ATTACHMENT B

LETTER TRANSMITTING FINAL CDC REPORT
TENNESSEE DEPARTMENT OF HEALTH
ENVIRONMENTAL HEALTH STUDIES AND SERVICE
COMMUNICABLE AND ENVIRONMENTAL DISEASE SERVICES

FEBRUARY 13, 2001

(8 Pages)

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NOV 1 2 2001
Tetra Tech EM Inc.
Cincinnati

February 13, 2001

FIELD(title) FIELD(first name) FIELD(last name)
FIELD(address)
FIELD(city), Tennessee FIELD(zip)

Dear FIELD(title) FIELD(last name):

Enclosed is the final report from the Centers for Disease Control and Prevention (CDC) on their investigation of the cleft lip/palate cluster in Dickson County. I will summarize the report and its recommendations and summarize what the Tennessee Department of Health and the Tennessee Department of Environment and Conservation are doing. A glossary is included to help explain some terms used in the report.

The CDC has confirmed that the rates of cleft lip/palate were increased in Dickson County between January 1, 1997, and October 31, 2000. They have not identified a cause. They recommend watching the numbers of infants born with cleft lip/palate in Dickson County to see if the cluster continues or if it stops. If the cluster continues, CDC recommends doing a more detailed study to try to find the cause. Please see the attached summary and the attached report from the CDC for details of the investigation.

The families with a child with a cleft lip/palate live in all parts of Dickson County. Most families use water supplied by the cities of Dickson, Charlotte, or Van Leer. Two families have private wells. Sampling of drinking water supplies of ten families has shown no evidence of contamination. The Environmental Assistance Office is sampling four more water supplies. If your water has not been tested and you want it tested, please call the Environmental Assistance Office at (615)687-7000. In addition, the Environmental Assistance Office has sampled many wells in Dickson County; the well and spring in the immediate vicinity of the landfill are the only areas outside the landfill to have shown any contamination.

Because the families with a child with a cleft lip/palate live in all parts of Dickson County, it is difficult to imagine how a source of air pollution could be related to the cluster. However, the Division of Air Pollution Control, in collaboration with the University of Tennessee, is modeling air concentrations of emissions from local industries. The air models predict the concentrations of chemicals in different parts of the county, taking into account such things as temperature, wind direction, wind speed, precipitation, and amounts of chemicals released from industries. Precise air modeling will give us a realistic picture of air concentrations of various chemicals in different parts of the county. We will let you know the results when we have them.

The Tennessee Department of Health is putting into place the procedures to actively find all new cases of cleft lip with cleft palate, cleft lip only, and cleft palate only that occur in Dickson County and the surrounding counties. If you know of any new cases or want to find out the status of the continuing investigation, please feel free to call me at any time at (615)741-5683.

Sincerely,

Bonnie S. Bashor, Director Environmental Health Studies & Services
Communicable and Environmental Disease Services

Summary of the CDC Report:

The Introduction summarizes what is known about the causes of cleft lip/palate and the rates found around the world. Cleft lip can occur with or without a cleft palate. Cleft lip with or without cleft palate is abbreviated as CL/P; cleft palate alone is abbreviated as CPO. CL/P is thought to have different causes than CPO. Several genes are involved in a complex way with CL/P and CPO.

CL/P is usually found in about 1-2 infants for every 1,000 births; CPO is usually found in about 0.7 infants per 1,000 births (or 7 infants per 10,000 births). Usually 33% of clefts affect the palate only (CPO); 46% affect the lip and palate; and 21% affect the lip alone (67% have CL/P).

The cause of CL/P and CPO is thought to be an interaction between genetic makeup and an environmental exposure during the first three months of the pregnancy. To medical researchers environment means anything except genetics - such as what we eat, drink, and smoke, viruses and bacteria we are exposed to, how we live our lives, the medications we take, and the chemicals we are exposed to. Environmental factors known to increase the risk of clefting are exposure of the fetus in the uterus to anti-epileptic drugs and isotretinoin (a medication for severe acne) taken by the mother. Other environmental factors that may increase the risk of clefting are maternal cigarette smoking, stress, obesity, diabetes, and exposure to some organic solvents. Use of multivitamins by the mother during the first trimester may decrease the risk of clefting.

The Preliminary Results section discusses how the cluster was confirmed, the results of the medical records review, and the result of the interviews. The Centers for Disease Control and Prevention (CDC) and the Tennessee Department of Health (TDH) found 18 infants born between January 1, 1997, and October 31, 2000 with CL/P or CPO in Dickson County. All mothers were living in Dickson County at the time of birth of the infant. The discussion of finding rates of clefting in Tennessee and Dickson County before 1997 is very involved. The result of the discussion is that no one can be sure what the rates of clefting are in Tennessee or were in Dickson County before 1997. The eighteen cases of clefting are more than we would expect, and the cluster is real.

Eleven (61%) infants had CL/P and 7 (39%) had CPO. This is very close to what is found around the world (67% with CL/P and 33% with CPO). The type and severity of clefting ranged from mild to severe.

Staff from the CDC completed interviews with 15 of the 18 mothers. The following table summarizes the information about possible risk factors for clefting.

Some risk factors related to clefting were found among the 18 mothers. But no one factor seems to account for the cluster in Dickson County. It is interesting that six infants were born prematurely, but that may be the normal rate among infants with CL/P.

Other studies of cleft lip and palate have shown clustering in geographical areas and over time, without an obvious explanation. CDC does not know if the cluster in Dickson County is due to some unidentified exposure, a normally high rate, or if it is a statistical variation that will disappear.

CDC recommends that we continue to follow the numbers of infants born with CL/P to see if the high rate continues or stops. If the rate continues to be high, CDC recommends a more detailed study to try to find the cause.

Table
Risk Factors Associated with Clefting

Possible Risk Factor	# Answering Yes	# Answering No
Vitamin use before pregnancy (protective)	2	13
Prenatal vitamin use (protective)	13	2
Smoking throughout 1st trimester	4	11
Some smoking in 1st trimester	7	8
Alcohol use in 1st trimester	0	15
Use of anti-epileptics or isotretinoin *	0	15
Obesity (BMI > 30) *	2	13
Gestational diabetes	2	13
Occupational exposure to relevant chemicals	0	15
Family history of clefting	1	14
Family history of tooth agenesis *	2	13
Preterm delivery	6	9
Municipal water source	13	2

* See the Glossary

GLOSSARY

22q11 deletion: an example of short-hand used by scientists to describe an abnormality of the DNA of a gene. 22 refers to chromosome 22; q refers to the long arm of the chromosome; 11 refers to band 11; a band is an area of a chromosome that stains darkly. The short-hand means that a deletion of a part of a gene has occurred in band 11 of the long arm of chromosome 22. This short-hand is said as "twenty-two q one one."

Alveolar ridge: the bony ridge where the sockets for teeth and their roots will form

Anomalies: Plural of anomaly, marked deviation from the normal, a defect. Used as in congenital anomalies (anomalies that a person is born with).

Anterior: in front of

Anti-epileptic drug: a medication that prevents seizures

Bifid uvula: the uvula is fleshy lobe at the back of the soft palate that hangs down. It is visible in the back of the mouth. A bifid uvula is one that has a split in it.

Body mass index: the weight in kilograms divided by the square of the height in meters. Weight in kilograms is equal to the weight in pounds divided 2.2. The height in meters is the height in inches times 0.0254. BMI = $(\text{pounds} \div 2.2) \div (\text{inches} \times 0.0254)^2$.

Case: a child in Dickson County with a cleft lip/palate born between January 1, 1997 and October 31, 2001.

Case Mother: the mother of a child with a CL/P who lives in Dickson County whom we interviewed

Chromosal abnormality: when the chromosome has a mistake in it

Chromosome: a structure in the nucleus that contains the genes of the individual; the structure is composed of a long chain of DNA that wraps itself into a spiral or helix. People have 46 chromosomes, arranged into 23 pairs.

Embryologic: an adjective of the noun embryo. In people, the developing child is called an embryo from about two weeks after fertilization to the end of the seventh or eighth week of gestation.

Environment: to medical researchers environment means anything except genetics - such as what we eat, drink, and smoke, viruses and bacteria we are exposed to, how we live our lives, the medications we take, and the chemicals we are exposed to.

First trimester: the first three months of a pregnancy

Gene: the unit of heredity found on chromosomes

Genetic susceptibility: another way to describe multifactorial disorders - see below

Hard palate: the rigid, bony part of the palate that is closer to the teeth

Incisive foramen: the area in the embryo where the incisor teeth will develop, including the area where the nerve for the incisor teeth will grow

Incomplete fusion: when the sides of the palate that are growing towards each other do not join successfully

Intrauterine: within the uterus

Isotretinoin: a medication used to treat severe acne; the most common brand name is Accutane

MACDP: Metropolitan Atlanta Congenital Defects Program

Malformation: abnormal or faulty formation, examples are a cleft palate, heart defect, or leg that does not develop correctly in the embryo or fetus

Mendelian genetics: Medelian genetics are responsible for some diseases. A Mendelian disorder in a person is one that is caused by a defect in one gene in one or both parents that the person inherits; another phrase that means the same thing is, simply inherited. Examples of simply inherited diseases are: color blindness (defect in the X chromosome), sickle cell anemia (the same defect in a chromosome in both parents), cystic fibrosis (the same defect in a chromosome in both parents), and Huntington's chorea (a defect in one chromosome of one parent)

Mucosal web: the thin layer of tissue the covers a submucous cleft; the tissue secretes mucous, so it is called mucosal

Multifactorial disorders: disorders that are caused by an interaction of multiple genes and environmental factors. Another phrase that means the same thing is, genetic susceptibility. Examples of multifactorial diseases are: cleft lip and palate, congenital heart disease, diabetes mellitus, multiple sclerosis, and hypertension (high blood pressure).

Muscular diastasis of the soft palate with mucosal integrity: separation of the muscles of the soft palate, while the tissues covering the palate and secreting mucous are intact

NBDPN: National Birth Defects Prevention Network

Notching of the posterior border of the hard palate: an indentation or depression at the back of the hard palate

Obesity: having a body mass index (BMI) greater than 30.

Orofacial: refers to the mouth and face

Overt: readily seen

Palatal shelves: during embryologic development, the secondary palate looks likes shelves as it grows

Palate: the partition separating the oral and nasal cavities

Parity: number of children that a mother has had

PDA: patent ductus arteriosus, an opening between the aorta and pulmonary artery that does not close at birth

Pharynx: the area in the throat between the mouth and nasal passages at one end and the larynx and esophagus at the other end

Primary palate: that part of the palate that comes from the area in the middle of the face where the nose is developing in the embryo

Rate: how often a disease appears among a certain number of people. For cleft lip/palate the rate is usually written as the number of infants born with cleft lip/palate for every 1,000 infants born in a year.

Secondary palate: most of the palate, formed when the sides of what will be the palate grow towards each other in the embryo

Soft palate: the fleshy part of the palate that is behind the hard palate, toward the throat

Submucous cleft: clefts of the hard or soft palate that are covered by a thin layer of tissue called the mucosal web

Syndrome: a group of signs and symptoms that occur together and characterize a particular abnormality

Teratogenic: an adjective of the noun, teratogen, a factor that causes the production of physical defects in the developing embryo

Tooth agenesis: some teeth never come in because the area where teeth are supposed to come in did not develop properly in the embryo

Velopharyngeal incompetence (VPI): the soft palate and pharynx do not function as they are supposed to

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Cincinnati

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FIELD(city), Tennessee FIELD(zip)

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if the cluster continues or if it stops. If the
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from the CDC for details of the investigati

The families with a child with a cleft lip/p
use water supplied by the cities of Dickso
wells. Sampling of drinking water supplies
contamination. The Environmental Assista
your water has not been tested and you wa
Office at (615)687-7000. In addition, the
wells in Dickson County; the well and spring in ... only
areas outside the landfill to have shown any con

Because the families with a child with a cleft lip ... is
difficult to imagine how a source of air pollutio ... e
Division of Air Pollution Control, in collaborati ... ling
air concentrations of emissions from local indus ... ns
of chemicals in different parts of the county, taking into account such things as temperature, wind
direction, wind speed, precipitation, and amounts of chemicals released from industries. Precise

Mo Barg,

1. CL/P infant been born in Dickson County since November 2000.

Bonnie Basher
11/7/2001

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NOV 1 2 2001

Attachment C

ATTACHMENT C

CASE FAMILY INFORMATION
BIRTH DEFECT RESEARCH ORGANIZATION

(5 Pages)

Betty Mekdeci: This information came from the "family group". The group name is: "TN Citizens for the Environment of Dickson"

6. Charity Campbell
383 Main Street lived on ~~Humming bird Lane~~
McEwen, TN 37101
Home Phone: 931-582-6659
Son: Joshua Robertson
DOB: 02-20-97
Date Conceived: 05-96 address where lived:
Water: Home/Public water home: public
Work/Public work: public
(conceived and gave birth while living in Dickson County)

7. Darcie and Scott Herkimer
743 Nels Adams Road
Dickson, TN 37055
Home Phone: 615-763-0097
Son: Samuel Herkimer
DOB: 11-24-98
Date Conceived: 03-98
Water: Home/Public
Work/Public

8. Jennifer Whited
121 Brookside Drive
Dickson, TN 37055
Home Phone: 615-446-8204
Son: Michael Netherton
DOB: 06-29-98
Date Conceived: 10-97
Water: Home/Public
Work/Public

Foster Parents:
Teresa and Phillip Hasley
1862 Rock Church Road
Charlotte, TN 37036
Home Phone: 615-789-0306

9. Brandi Warren
513 Pleasant Valley Drive
Dickson, TN 37055
Home Phone: 615-740-1670
Son: Wade Eleazer
DOD: 01-28-98
Date Conceived: 08-97
Water: Home/Well
Work/Public

8/30 confirmed ~~Humming bird Lane~~ ~~Heights~~ McGray between College street

8/27 left Cudo: will call back ~~Humming bird Lane~~ 6/26/01 Betty Mekdeci

10. Shonda Heflin
2121 Highway 125 #185
Ashland City, TN 37015
Home Phone: 615-792-9755
Daughter: Sydney Stivers
DOB: 02-10-00
Date Conceived: 05-99
Water: Home/Public
Work/ unknown

address where lived: unknown
water home:
work:

(Conceived and gave birth while living in Dickson County)

11. Tara and Ronald Morris
221 Oak Hill Drive
Vanleer, TN 37181
Home Phone: 615-763-6144
Son: Troy Morris
DOB: 10-26-99
Date Conceived: 03-99
Water: Home/Public
Work/Public

12. Amy and Travis Wood
110 Red Oak Circle
Dickson, TN 37055
Home Phone: 615-740-9375
Daughter: Lauren Wood
DOB: 09-15-99
Date Conceived: 01-99
Water: Home/Public
Work/Public

13. Priscella Miles/Jason Stewart
4377 Highway 70 West
Dickson, TN 37055
Home Phone: 615-441-3889
Son: Dakota Stewart
DOB: 02-16-00
Date Conceived: 05-99
Water: Home/Public
Work/Public

14. Melissa and Steven Jones
1005 Harman Springs Road
Dickson, TN 37055
Home Phone: 615-446-6354
Daughter: Mya Elizabeth Jones
DOB: 10-13-00
Date Conceived: 01-00
Water: Home/Public
Work/Public

6/11/01
John and Sandra Underhill:
- this the location near the landfill.
Melissa
- lived there until Jan 2001.
- ~ a couple miles north of town.
Worked in Nashville
Address: same (1005
Water home: "City water"
~~[illegible]~~ have a well

(Grandparents live near landfill-spent time at this home)

15. Keisha and Tony Fambrough
122 South 3rd Street
Dickson, TN 37055
Home Phone: 615-740-0486
Daughter: Autumn Fambrough
DOB: 03-15-00
Date Conceived: 06-99
Water: Home/Public
Work/Public

16. Carol and Shawn McCutchen
200 Plantation Court
Dickson, TN 37055
Home Phone: 615-441-4864
Son: Stewart McCutchen
DOB: 03-20-99
Date Conceived: 06-98
Water: Home/
Work/

17. Heather Norman
Contact- Eileen Norman
123 Payne Springs Road
Dickson, TN 37055
Home Phone: 615-446-6878
Daughter: Sophie Norman
DOB: 05-22-99
Date Conceived: 08-98
Water: Home/Public

(Lived in Memphis, visited relatives in Dickson every weekend)

18. Rebecca Pierce
535 Park Court
Nashville, TN 37211
home phone: 615-333-0895
Son: Stephen Andrew Pierce
DOB: 6/21/97
Exposed to Dickson water during pregnancy.

address of exposure
water home:
work:

frequency exposure:
date conceived:

called 6/18
no save info request
to BDR for C
Secretary (Betty is
out of town till 6/25).

Summary of CPL / CPO Locations

1. Family 1: 495 Baker Road, Dickson
   Water: home well and work public
   Conception: 8/97

2. Family 2: 304 Lovell Avenue, Dickson
   Water: home well and work public
   Conception: 9/97

3. Family 3: 14355 Tidwell Switch Road, Dickson
   Water: home public and work public
   Conception: 1/98

4. Family 4: 400 Log Wall Road, Dickson
   Water: home public and work public
   Conception: 1/97

5. Family 5: 220 Shoulder Strap Branch Lane, Town of Van Leer
   Water: home well and work public
   Conception: 7/97

6. Family 6: label location as "address undetermined" and plot in downtown Dickson
   Water: home public and work public
   Conception: 5/96

   6/18
   called 2 numbers
   could not locate

7. Family 7: 743 Nels Adams Road, Dickson
   Water: home public and work public
   Conception: 3/98

8. Family 8A: 121 Brookside Drive, Dickson
   Water: home public and work public
   Conception: 10/97

   Family 8B Foster Home: 1862 Rock Church Road, Town of Charlotte

9. Family 9: 513 Pleasant Valley Drive, Dickson
   Water: home well and work public
   Conception: 8/97

10. Family 10: label location as "address undetermined" and plot in downtown Dickson
    Water: home public and work unknown
    Conception: 5/99

S:\projectsstart/dicksonlandfill/summary of CPL by addressandtele

11. Family11: 221 Oak hill Drive, Town of Van Leer
    Water: home public and work public
    Conception: 3/99

12. Family 12: 110 Red Oak Circle, Dickson
    Water: home public and public
    Conception: 1/99

13. Family 13: 4377 Highway 70 West, Dickson
    Water: home public and work public
    Conception: 5/99

14. Family 14: 1005 Harmon Springs Road, Dickson
    Water: home public and work public
    Conception: 1/00

15. Family 15: 122 South 3rd Street, Dickson
    Water: home public and work public
    Conception: 6/99

16. Family 16: 200 Plantation Court, Dickson
    Water: home unknown and work unknown
    Conception: 6/98

17. Family 17: 123 Payne Springs Road
    Water: home public and work Memphis
    Conception: 8/98

18. Family 18:
    Water: home ____ and work _____
    Conception: ____

ATTACHMENT D

CLEFT DEFECT CLUSTER ARTICLE
THE DICKSON HERALD

SEPTEMBER 22, 2000

(2 Pages)

DWS/NEAC

Post-it® Fax Note 7671	Date	# of pages ▶
To Kim Olson	From Louis P	
Co./Dept.	Co. DWS	
Phone #	Phone # 687-70	
Fax # 532-0740	Fax # 687-707	

Post-it® Fax Note 7671	Date 9/24/00	# pa 2
To David Dransham	From Louis	
Co./Dept.	Co.	
Phone #	Phone #	
Fax # 532-0503	Fax #	

AAA 1/2
AEE 9/25
MS 9/25
EW 9/25
~~SHS~~ 9/27

The Dickson Her[ald]

FRI 9/22/00

"Your Hometown Newspaper Since 1907"

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A Gannett Newspaper

Study points to cleft defect cluster

Landfill, business could have triggered deformities via chemical solvent release

By KIM CONNER
Staff Writer

A national birth defects research group has identified two major toxins in Dickson County that may be the cause of an inordinate number of cleft deformities.

Toluene and trichloroethylene (TCE), both manmade chemical solvents, are triggers for the birth defect that occurs during the first trimester of pregnancy. Both have been found in Dickson County, said Betty Mekdeci, director of Orlando-based Birth Defect Research for Children.

According to information presented to parents of children with the oral cleft defects, TEC was found in a private well in 1991 and in a public well and the public water supply of Dickson in 1997. The chemical is of main concern because studies have indicated a possible association between TCE in drinking water and increases in oral clefts and other birth defects, Mekdeci said.

"In my opinion, from the documents I have seen, the landfill should be closed," Mekdeci said. "It (the studies) certainly doesn't make you feel good."

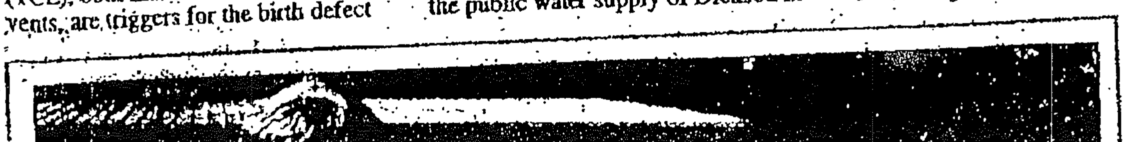
If TCE is found to be the etiology behind the cleft defects, said Mekdeci, "then the likelyhood is that it is causing more."

Though drinking water is thought to be the major conduit for TCE into a pregnant woman's system, more than 50 percent of exposure comes from showering or bathing.

"TCE is lipofilic, it stores up in your body fat," Mekdeci said. "During pregnancy, your body draws down on your reserves and uses that body fat."

Before any potential cause-effect relationship between TCE and the oral cleft cluster in Dickson can be determined, however, the community would have to prove that each mother was "exposed to contaminated water during the first three months of her pregnan-

SEE CLEFT, PAGE A5



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• FROM PAGE A1

cy," said Mekdeci in her report. "The amount of TCE in the water would also have to be high enough to be associated with oral clefts."

"We are aware that there have been minute amounts of TCE found in a spring and have been working towards finding the source," said Jim Linn, director of the county's sanitary landfill. "As of this point, we have not connected a source back to the landfill."

The second chemical of concern is toluene, an industrial solvent. Quebecor Printing, located in the industrial park, is releasing approximately 1.4 million pounds of toluene into the air each year, according to Mekdeci's report. That amount, however, is within the applicable standards for the company, said Ann O'Brien, director of environmental affairs for the U.S. firm's operations.

"We're in compliance with all state and federal regulations, and that includes the most recent and most stringent MAC standards," she said. "Those [MAC] standards were specifically designed to protect community health."

But, neither O'Brien, nor Benoit Brasseur, corporate director of environmental affairs for Quebecor Printing, had been informed of the study, nor had they been told toluene could be a trigger for oral cleft deformities.

Toluene, listed as a developmental toxin, can also cause birth defects. Toluene is heavier than air, Mekdeci said in her report to the parents, so releasing it from a smokestack may mean it's not remaining in the upper air.

According to the Environmental Defense (Fund) scorecard, toluene was the major pollutant discarded in Dickson County in 1997, with almost 1.5 million pounds being released. According to the scorecard, Quebecor ranked 90-100 percent as being the "dirtiest" or "worst" of facilities for total environmental releases; at 100 percent for noncancer risk score for air and water releases; and 90-100 percent for air releases of recognized developmental toxins.

A county resident contacted BDRC in March after she noticed "an unusual number of cases of cleft palate" reported in Dickson County. BDRC sent questionnaires to distribute to the families whose children had been identified and began researching the possible links between cases.

Oral cleft defects are expected at a rate of about 1 per 1,000 births, which would suggest two children born with cleft lip or palates, or both. Since 1997, 14 of the 1,700 children born to parents in Dickson County have had cleft lip or palate.

"This is an 800 percent increase over the expected amount," said Mekdeci. "That is impressive. Though it doesn't mean they all have the same cause, it does raise speculation."

After plotting the locations of each family, Mekdeci said BDRC found they were clustered in the southwestern quadrant of the county.

Oral cleft defects are caused by at least dual factors, Mekdeci said — a genetic predisposition coupled with a triggering factor. The defect, located in the structures of the mouth, is a split or separation in the infant's lip and/or palate. Cleft lip means the two sides of the upper lip did not grow together properly, while a cleft palate is a split or opening in the roof of the mouth.

The defect occurs during the first trimester of pregnancy, usually between the sixth and ninth weeks, Mekdeci explained. During that time, parts of the roof of the mouth and upper lip normally join together. When this joining doesn't take place, a child develops a cleft lip and/or palate.

"With birth defects," said Mekdeci, "the most acute defects happen when there is sudden exposure during the critical weeks for a particular development."

While families that have a history of oral clefts are more likely to have children with the defect, it can also occur in families without such a background.

Researchers believe many factors contribute to oral clefts, with environmental factors interacting with specific genes to interfere with the patterns of normal palate closure and lip development. Besides chemical interactions, scientists are considering reactions to certain drugs, maternal smoking, radiation and vitamin deficiencies as possible triggering agents.

Parents of these children are understandably concerned, Mekdeci said.

"They are coming to grips with the increase in clefts in this community," she said. "Finding these triggers puts a different spin on things."

Mekdeci said parents have several choices, including civil litigation and applying for environmental justice grants or Superfund to correct the problem if it is determined. But residents' main objective is to rectify the problem, she said.

"We have to come up with solutions," Mekdeci said. "What kinds of legacy are we going to leave our children if they can't function in normal society?"

The Environmental Protection Agency is slated to investigate the situation within the next month, Mekdeci said.

Oral clefts are among the most common birth defects, with more than 250,000 Americans having a cleft condition. Of those, 25 percent have a cleft palate alone; 25 percent only a cleft lip; and 50 percent having both cleft lip and palate.

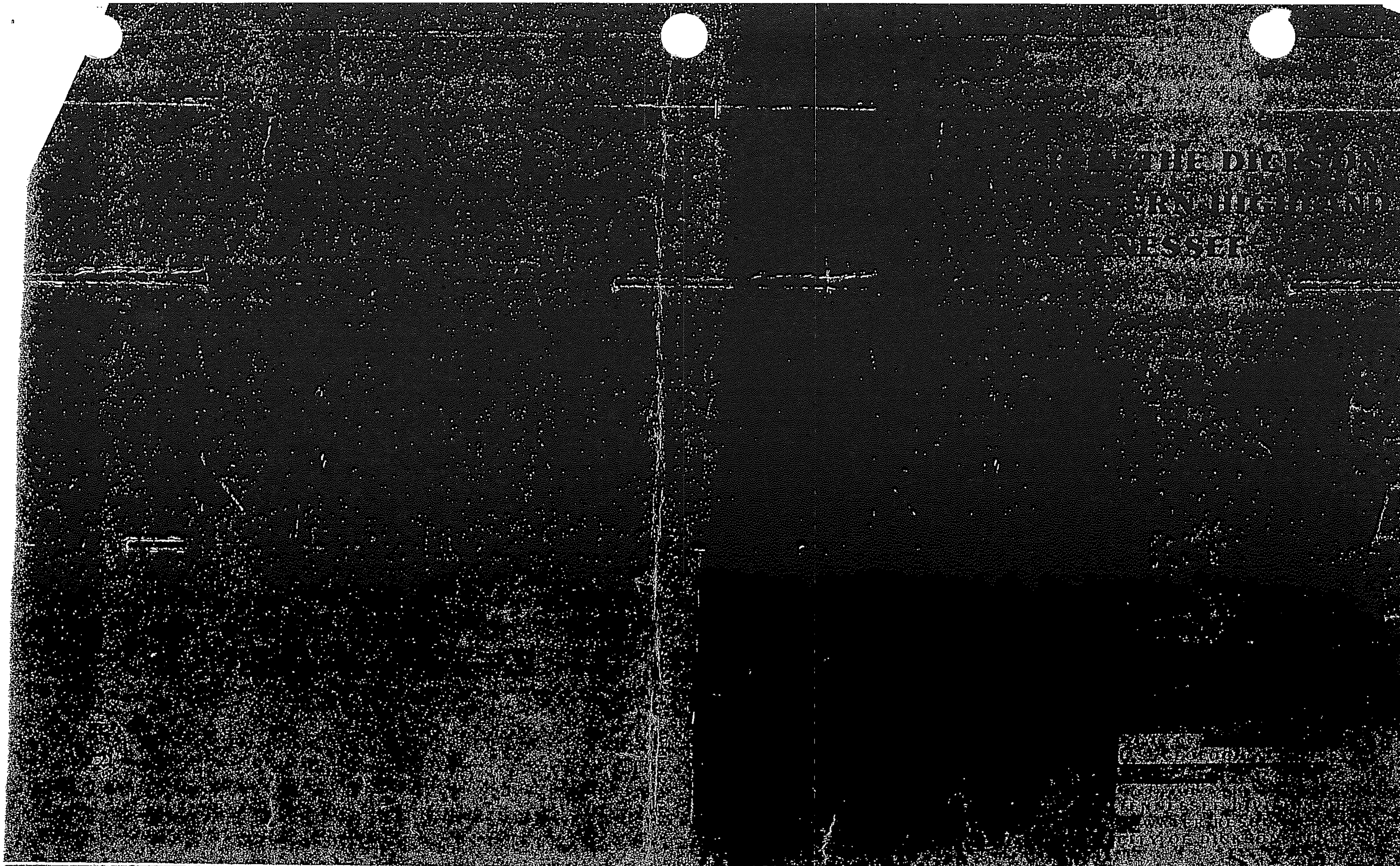
Parents of children in Dickson County who were born with oral clefts should send a letter with contact information to "Information," P.O. Box 411, Burns, TN 37029, or one can send an e-mail message to dicksoncleftinfo@aol.com. Parents are encouraged to make contact so further research can be completed.

ATTACHMENT E

GROUNDWATER IN THE DICKSON AREA
OF THE WESTERN HIGHLAND RIM OF TENNESSEE
U.S. GEOLOGICAL SURVEY

1994

(27 Pages)



USGS
Mike Bradley
837-4700

Park
Suite 100

GROUND WATER IN THE DICKSON AREA OF THE WESTERN HIGHLAND RIM OF TENNESSEE

Michael W. Bradley

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations 82-4088

Prepared in cooperation with the
TENNESSEE DIVISION OF WATER RESOURCES and the
CITY OF DICKSON, TENNESSEE

Nashville, Tennessee
1984

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
A-413 Federal Building
U.S. Courthouse
Nashville, Tennessee 37203

Copies of this report can be purchased from:

Open-File Services Section
Western Distribution Branch
U.S. Geological Survey
Box 25425, Federal Center
Lakewood, Colorado 80225
(Telephone: (303) 236-7476)

CONTENTS

ILLUSTRATIONS

TABLES

ABBREVIATIONS AND CONVERSION FACTORS

Factors for converting inch-pound units to International System of units (SI) and abbreviation of units:

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.59	square kilometer (km^2)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
pound (lb)	0.4536	kilogram (kg)
ton	0.9072	megagram (Mg)
micromho per centimeter (μmho/cm)	1	microsiemens per centimeter (μS/cm)

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°F = 1.8°C + 32$$

<u>National Geodetic Vertical Datum of 1929 (NGVD of 1929)</u>: A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

GROUND WATER IN THE DICKSON AREA OF THE WESTERN HIGHLAND RIM OF TENNESSEE

Michael W. Bradley

ABSTRACT

A hydrologic study of the Dickson, Tenn., area provided additional information on the occurrence of ground water in the Mississippian carbonate rocks of the western Highland Rim. Twenty-six wells were drilled to determine the occurrence of ground water in relation to topographic position, regolith thickness, streamflow gains or losses, lithology of the underlying formations, and linear features.

26 wells

Yields of 26 test wells ranged from 0 to about 300 gallons per minute and averaged about 68 gallons per minute. Nine wells yielded 80 to about 300 gallons per minute; specific capacities ranged from about 0.71 to 12.7 gallons per minute per foot of drawdown. Seven of these nine wells yielded water from solution openings in the Warsaw Limestone. The other two wells yielded water from gravel and sand in the regolith. Aquifer tests were conducted on two wells. One well was pumped at an average rate of 350 gallons per minute for 72 hours with 39.77 feet of drawdown. The second well was pumped for 8 hours at 120 gallons per minute with 20.86 feet of drawdown. The water from both wells was of generally good quality. Water from one well had a dissolved solids concentration of 170 milligrams per liter. The dissolved solids in the water from a second well was estimated from specific conductance as about 160 milligrams per liter.

Thick regolith and the presence of fine-grained limestone interbedded with coarse-grained limestone near the base of the regolith appear to be significant conditions for the development of solution openings that yield large amounts of water. Seventy percent of the test wells in which these conditions occurred yielded 80 gallons per minute or more.

INTRODUCTION

The need for alternative sources of water has emphasized the need for additional information on the occurrence of ground water in carbonate rocks. In the past, these aquifers have been used, for the most part, as rural domestic water sources. Development of these aquifers for municipal and industrial purposes is deterred by their highly variable water-bearing properties; low-yielding wells are common and the occurrence of large supplies is unpredictable. A three phase study was conducted near Dickson, Tenn., to acquire a better understanding of the ground-water system.

The study had three objectives:

- To describe the ground-water hydrology of the western Highland Rim in the vicinity of Dickson,

- To test concepts of ground-water occurrence by drilling test wells at sites selected on the basis of hydrologic criteria, and
- To acquire and interpret data on the quantity and quality of ground water and on the geologic environment in which it occurs.

To accomplish these objectives the first phase of the study included interpretation of well and spring records, water-quality data, streamflow measurements, aerial photographs, and geologic data. During the second phase, test sites were selected and a total of 26 wells was drilled. In the third phase, aquifer tests were conducted to determine aquifer properties. Water samples were collected for water-quality analyses.

This study was conducted by the U.S. Geological Survey, in cooperation with the city of Dickson and the Tennessee Division of Water Resources and is part of a larger study of the carbonate rocks of the Highland Rim in which the concept of ground-water occurrence is being tested in specific areas.

DESCRIPTION OF THE STUDY AREA

The Dickson area lies on the rolling plateau of the western Highland Rim, a section of the Interior Low Plateaus physiographic province. The study area is within Dickson County and approximately 40 miles west of Nashville (fig. 1). The 104-square-mile area lies along the drainage divide between the Tennessee and Cumberland River basins. The major streams are the East and West Piney Rivers which drain the western and southern part of the area and Jones Creek which drains the northeastern part. These streams are deeply incised into the plateau providing about 300 feet of relief. Altitudes range from near 600 feet in the valley of Piney River to about 900 feet above sea level.

The Dickson area has a temperate climate, mean monthly temperature ranges from 39 °F in January to 79 °F in July (fig. 2). The mean annual temperature is 59 °F. The Dickson area receives about 50 inches of precipitation in a normal year. However, most of the precipitation falls during the late winter and ~~early spring. Mean monthly precipitation ranges from 2.54 inches in October~~ to 5.52 inches in March (fig. 3).

GEOLOGY

scaloosa Gravel E
.Louis Miss
rsaw Miss
Paine Miss

Formations exposed on the northwestern Highland Rim in the Dickson area include, in descending order, the Tuscaloosa Gravel of the Cretaceous Period and the St. Louis Limestone, the Warsaw Limestone, and the Fort Payne Formation of the Mississippian Period (fig. 4). The regional dip of the formations is toward the northwest (Marcher, 1962a). Local structural features include lows to the southwest and northeast parts of the study area that are separated by an east-west trending anticline under the city of Dickson (figs. 4 and 5).

The Tuscaloosa Gravel consists of chert gravel, sand, silt, and clay. The chert gravel is composed of well-rounded fragments up to 6 inches in diameter, and was derived from the Camden Chert of Devonian age or locally from the St. Louis, Warsaw, and Fort Payne. Because of its isolated nature and limited distribution, the Tuscaloosa is not a significant source of ground water.

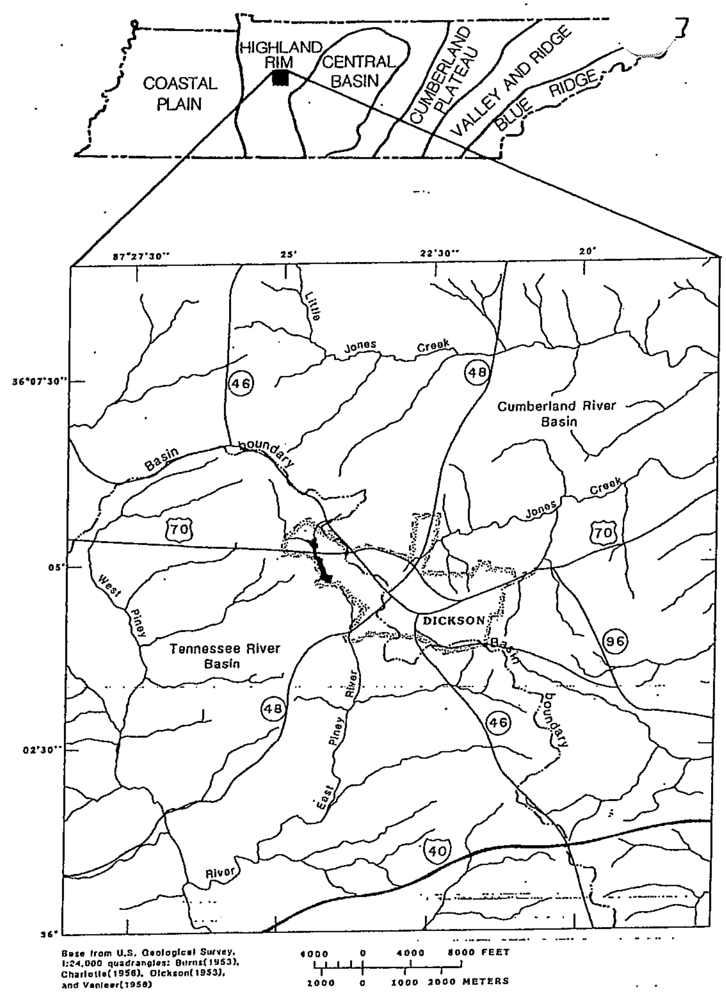


Figure 1.— Location of the Dickson area, Tennessee.

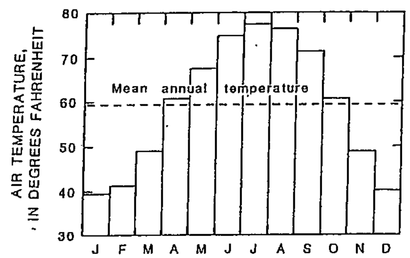


Figure 2.--Mean monthly air temperature measured at the Dickson station (temperature data from National Oceanic and Atmospheric Administration, 1979).

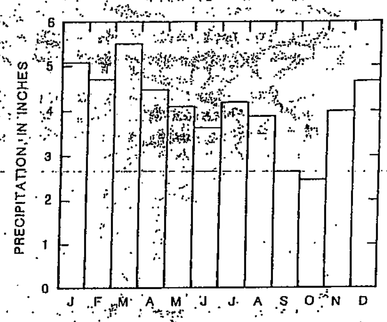
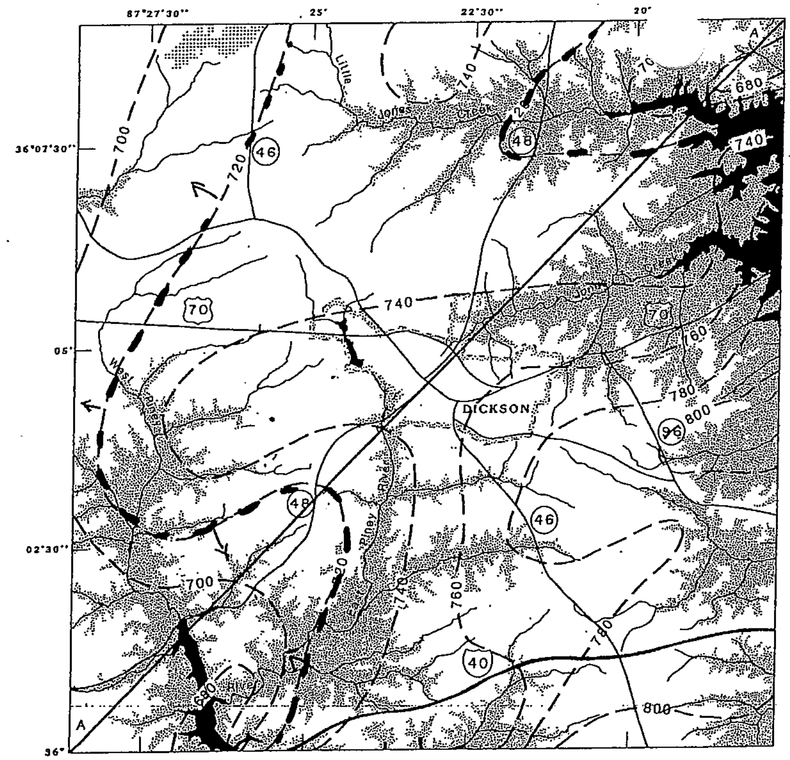


Figure 3.--Mean monthly precipitation measured at the Dickson station (precipitation data from National Oceanic and Atmospheric Administration, 1979).



Base from U.S. Geological Survey, 1:24,000 quadrangles: Burns(1953), Charlotte(1958), Dickson(1953), and Vanleer(1956)

4000 0 4000 8000 FEET

1000 0 1000 2000 METERS

Geology modified from Marcher, Bingham, and Lounsbury (1964)

EXPLANATION

CRETACEOUS

Tuscaloosa Gravel

MISSISSIPPIAN

St. Louis Limestone

Warsaw Limestone

Fort Payne Formation

—720— Structural contours on top of the Warsaw Limestone. Contour interval 20 feet. Dashed where approximately located. National Geodetic Vertical Datum of 1929

A ——— A' Line of cross section (See figure 5)

Figure 4.-- Geology and structure of the Dickson area.

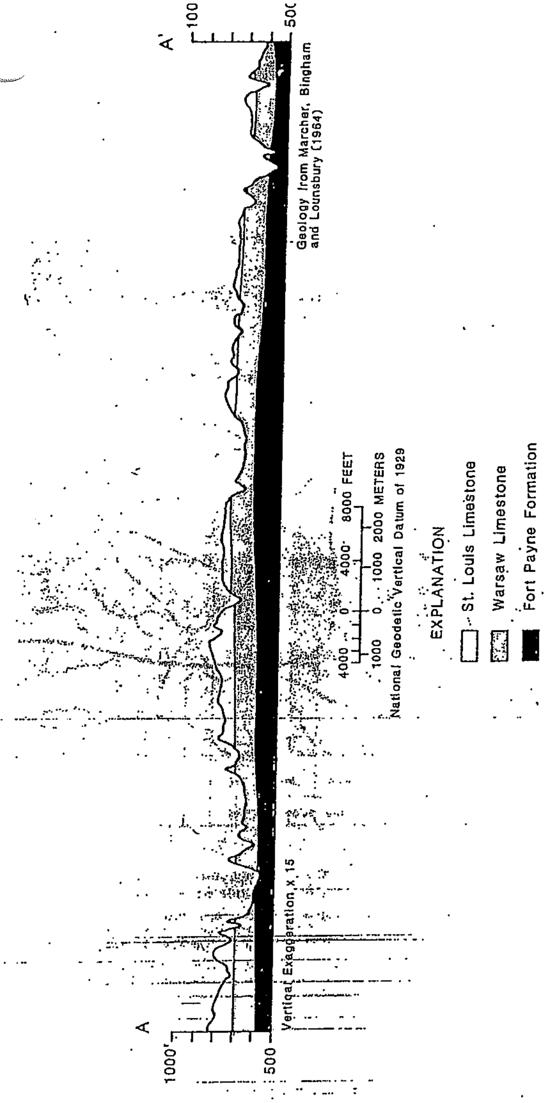


Figure 5.--Geologic cross section of the Dickson area.

St. Louis

The St. Louis Limestone, which caps most of the uplan generally represented at land surface only by a residual clay soil conta blocks and nodules of chert. The St. Louis is a yellowish-brown fine-grained cherty limestone which locally includes beds of medium- to coarse-grained fossil-fragmental silty limestone similar to the underlying Warsaw Limestone. The St. Louis regolith contains chert which is dark, very dense, and brittle, and in places is characterized by round chert "cannonballs" (Marcher and others, 1964). Regolith is the mantle of unconsolidated material which overlays the bedrock.

Warsaw

The Warsaw Limestone is typically a thick-bedded, light colored, medium- to coarse-grained, fossil fragmental limestone. In the Dickson area it is approximately 100 feet thick. The sand size fossil fragments were derived primarily from crinoids and bryozoans. Quartz and calcite are the main minerals present, but glauconite and pyrite occur locally in very small amounts. Locally, the Warsaw Limestone contains fine-grained, cherty beds which are typical of the underlying Fort Payne Formation. The Warsaw-Fort Payne contact is generally conformable with gradation and possible inter-tonguing occurring between the two formations.

Ft Paine

The Fort Payne Formation is typically a calcareous, dolomitic, very cherty siltstone. Maximum thickness in the Dickson area is approximately 250 feet. Chert occurs throughout the formation in distinct beds, as irregular discontinuous beds or nodules, and within the matrix of the limestone and dolomite. Small cavities (less than 2 inches in diameter) contain quartz or calcite. Some gypsum occurs in the lower part of the Fort Payne. Glauconite and pyrite also occur in small quantities. Some beds in the Fort Payne are medium- to coarse-grained, fossil fragmental limestone similar to the typical Warsaw Limestone.

Chatt. Shale

Underlying the Mississippian formations is the Chattanooga Shale, a fissile black shale approximately 20 feet thick. Below this is a thick sequence of Silurian and older rocks consisting of limestone, dolomite and calcareous siltstone (C. R. Burchett and Ann Zurawski, written commun., 1979). For additional discussion of the geology of the Dickson area, see Marcher and others (1964).

HYDROLOGY

CONCEPT OF GROUND-WATER OCCURRENCE

Carbonate rocks underlying the Dickson area have little intergranular permeability. Secondary permeability features, primarily solution enlarged bedding plane openings, transmit most of the water (fig. 6). Moore and Bingham (1965) reported that the largest amounts of ground water occur in solution openings in soluble limestone, such as some beds in the Warsaw and St. Louis Limestone.

The St. Louis Limestone and locally the upper part of the Warsaw generally have weathered to a clay regolith in the Dickson area. The regolith has low permeability but has an important role in ground-water occurrence in this area. The regolith stores a large amount of water and slowly releases it to solution openings in the underlying limestone. There the solvent action of the water

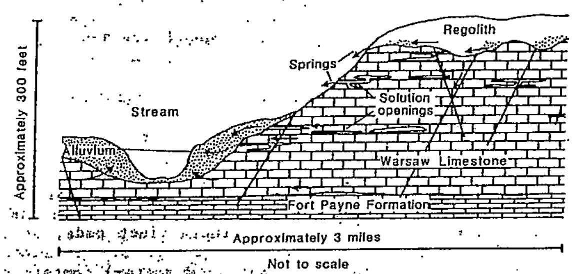


Figure 6.--Concept of ground-water occurrence and flow in the Dickson area.

enlarges openings and increases permeability. The occurrence of thick regolith over the soluble Warsaw Limestone is conducive to the development of high yielding solution openings.

The ground-water system is recharged primarily from precipitation on the uplands. Water moves down through the regolith and into solution openings and fractures in the limestone. Marcher and others (1964) estimated that about 12 percent of the total precipitation recharges the ground-water system. Once the water is in the limestone, it moves along the solution openings and vertical fractures to discharge points at springs and along streams.

Springs and stream segments which gain flow are positive indicators of the presence of ground-water reservoirs (Rima and Goddard, 1979). The springs in this area, with the exception of Payne Spring, all issue from the Warsaw Limestone. This indicates that the Warsaw is a ground-water reservoir and the dense cherty Fort Payne Formation is generally an underlying confining layer. However, some wells yield water from solution openings in the Fort Payne.

WELL RECORDS

Data on wells in the Dickson area are in the files of the Tennessee Division of Water Resources and U.S. Geological Survey. Since 1963, water-well drillers have been submitting reports to the State on the wells that they drill. Data on yield and casing length were obtained from these driller reports.

Reported well yields for 165 wells in the area (fig. 7) range from less than 1 to about 100 gal/min. Sixty-nine percent of the wells yield less than 10 gal/min. However, 22 percent yield 15 gal/min or more. There is no clear pattern to the distribution of well yield and location (fig. 8). Wells yielding more than 15 gal/min are scattered throughout the area and occur in stream valleys and uplands.

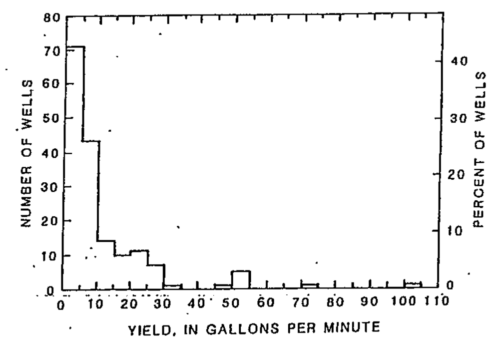


Figure 7.--Frequency distribution of reported well yields (data from Tennessee Division of Water Resources, unpublished data).

Casing lengths have been reported for 226 wells in the Dickson area. The lengths range from a minimum of 6 feet to a maximum of 188 feet. About half of the wells are cased to between 40 and 79 feet (fig. 9). Because State regulations require that well casing be set into bedrock, most reported casing lengths are at least as great as the regolith thickness and may be greater (Burchett and Zurawski, written commun., 1979). Casing lengths were used to approximate the regolith thickness (fig. 10).

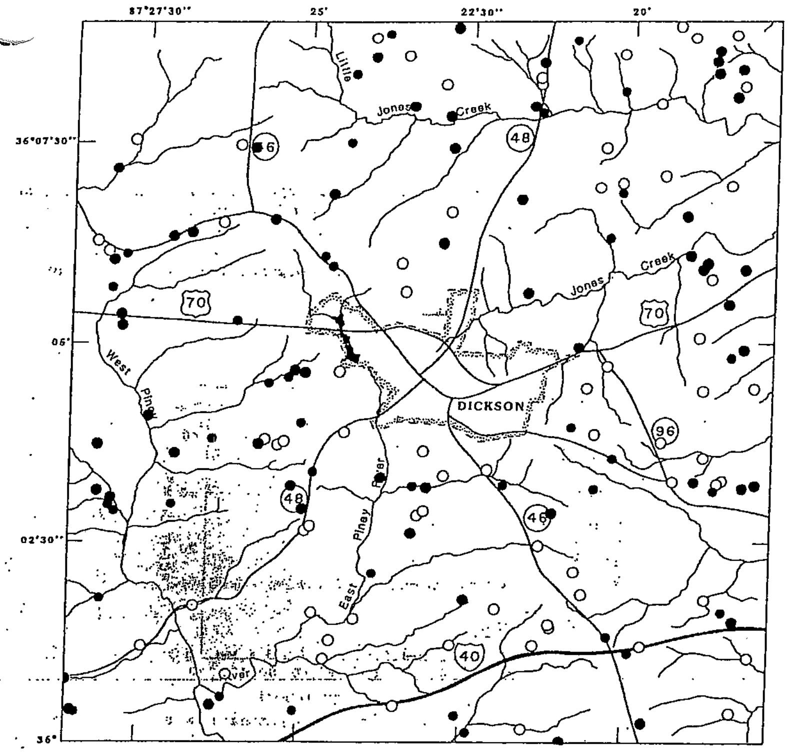


Figure 8.– Reported well yields in the Dickson area.

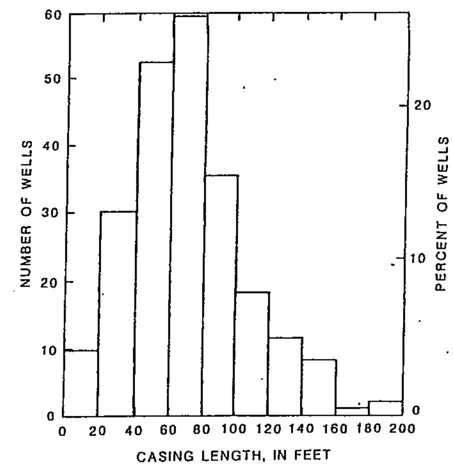


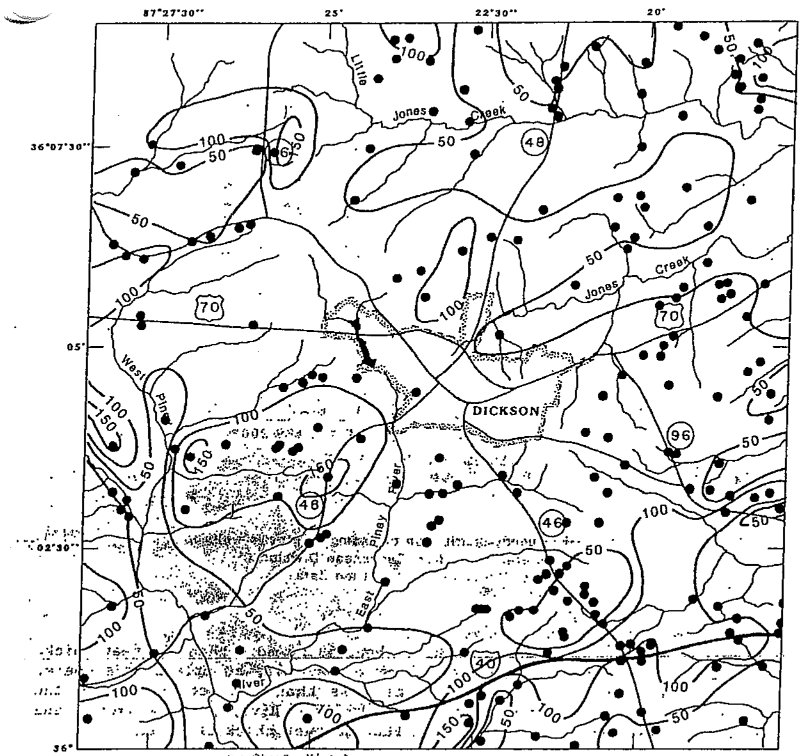
Figure 9.--Frequency distribution of casing lengths in wells in Dickson area (data from Tennessee Division of Water Resources, unpublished data).

Regolith in the uplands is generally about 50 to more than 150 feet thick. One exception is southeast of Dickson along Highway 46, an upland area where, based on casing lengths, the regolith is less than 50 feet thick. In the valleys of the major streams, East and West Piney Rivers, Jones Creek, and Little Jones Creek, the regolith is less than 50 feet thick (fig. 10).

GROUND-WATER LEVELS

Ground water in the Dickson area flows from recharge areas where water level elevations are high, to discharge points at lower elevations. Water levels in 59 wells were measured in March 1960 (Marcher and others, 1964) and ranged from 0 to 110 feet below land surface. It is likely that water levels are similar now (1980) as ground-water pumpage in the area has not changed greatly.

A water level contour map modified from Marcher and others (1964) is based on the March 1960 water levels and the altitudes of nine springs (fig. 11). This map shows high water-level altitudes under the drainage divide which runs northwest to southeast through Dickson with the highest water levels northwest



Base from U.S. Geological Survey, 1:24,000 quadrangles: Burns(1953), Charlotte(1958), Dickson(1953), and Vanleer(1958)

4000 0 4000 8000 FEET

1000 0 1000 2000 METERS

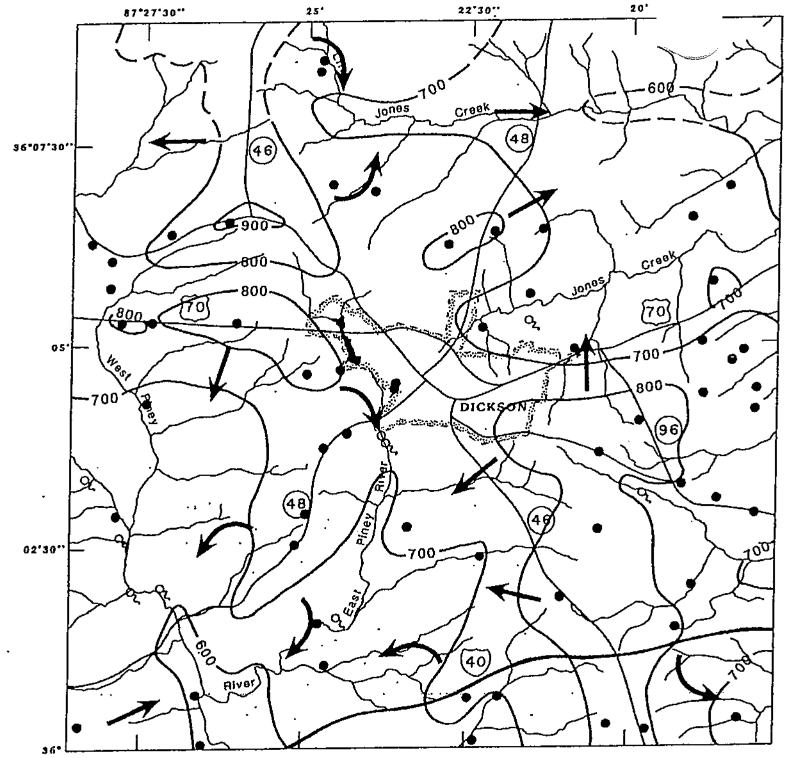
Data from Tennessee Division of Water Resources, unpublished data (1979)

EXPLANATION

—100— LINE OF EQUAL THICKNESS OF REGOLITH—Interval 50 feet. Datum is land surface

● Well location

Figure 10.—Regolith thickness based on casing lengths.



Base from U.S. Geological Survey, 1:24,000 quadrangles: Burns(1953), Charlotte(1958), Dickson(1953), and Vanleer(1958)

4000 0 4000 8000 FEET

1000 0 1000 2000 METERS

Hydrology modified from Marcher, Bingham, and Lounsbury (1964)

EXPLANATION

—600— — POTENTIOMETRIC CONTOUR—Shows altitude of water table, March 1960. Dashed where approximately located. Contour interval 100 feet. National Geodetic Vertical Datum of 1929

● Wells with water levels measured March, 1960

Springs

Direction of ground-water flow

Figure 11.—Ground-water levels and direction of flow.

of Dickson. The water table is as much as 300 feet lower in altitude in the valleys of the major streams (Burchett and Zurawski, written commun., 1979). The direction of ground-water flow is similar to the surface drainage; flow is away from uplands and toward lower water-level altitudes in the valleys.

SPRING DATA

Springs are natural outlets for ground water and occur where land surface intersects the water table. Most of the large springs in the Dickson area (fig. 12) discharge from near the bottom of deeply incised hollows (Marcher and others, 1964).

Discharge measurements were made during July 1979 at six springs in the Dickson area. Two springs, Walnut Grove Spring and Grassy Spring, had the lowest discharge of the six springs measured (table 1). The measured yield of the four springs along West Piney River ranged from 0.57 to 1.78 cubic feet per second (ft^3/s). Payne Spring was measured in September 1978, with a flow of 0.20 ft^3/s. Eight discharge measurements ranging from 0.13 to 0.79 ft^3/s were made at Tice Spring from September 1980 through June 1981. Specific conductance of water from the springs ranged from 175 to 295 micromhos per centimeter (μmhos/cm) and pH ranged from 7.0 to 7.7 (table 1).

Discharge measurements have been made periodically from 1931 through 1979 at Fielder and Bruce Springs (table 2). Fifty-seven measurements have been made at Fielder Spring; Bruce Spring has been measured 17 times during the same period as Fielder Spring. Discharge from Bruce Spring is consistently lower than discharge from Fielder Spring.

STREAMFLOW DATA

Streamflow measurements were made on July 19, 1979, at 96 sites along streams in the study area (fig. 13). The streams were dry at 27 of the sites. All but two of the dry sites have drainage areas of less than 1 square mile. The largest drainage area was 1.68 square miles. The average streamflow for all 96 sites was 0.26 cubic foot per second per square mile. If the 27 dry sites were omitted, the average was 0.36 cubic foot per second per square mile.

The change in streamflow per additional square mile of drainage area between sites was determined for each site in order to delineate stream reaches which are gaining more ground water than other stream reaches (fig. 13). The gaining reaches of the streams are generally draining upland areas which have some relatively high reported well yields. The gaining reaches of streams, similar to springs, indicate discharge from the ground-water reservoir.

Low-flow discharge measurements have been published (Gold, 1980) for 10 sites within the study area (fig. 14 and table 3). Low-flow measurements are made at a time when there is no overland runoff from precipitation, and flow is sustained by discharge from the ground-water system.

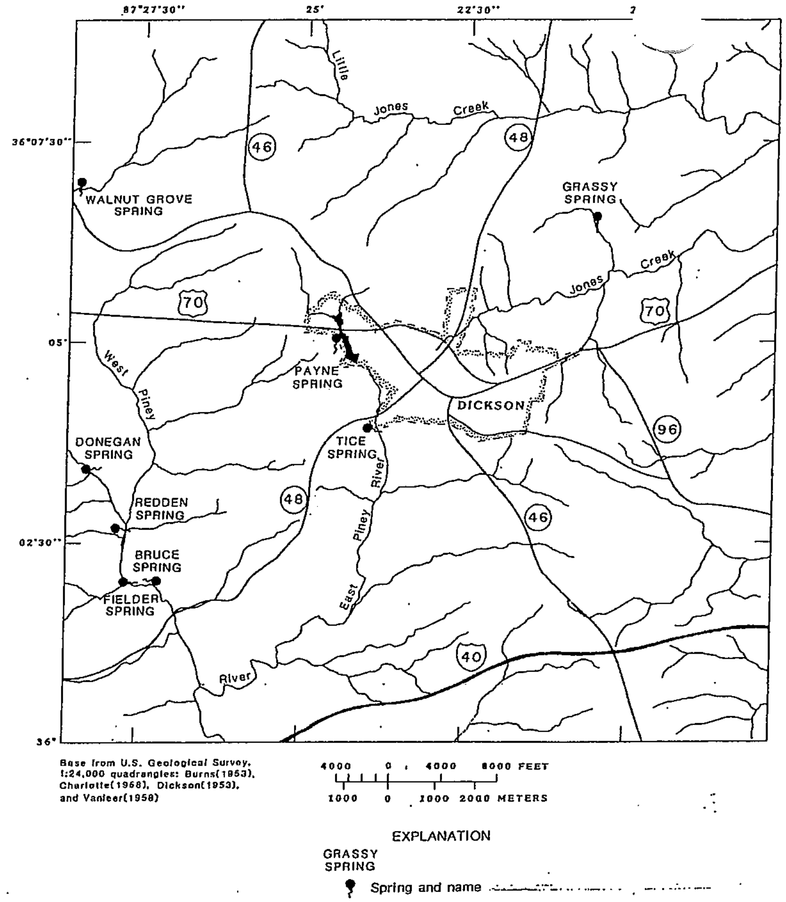


Figure 12.— Springs in the Dickson area.

Table 1.--Discharge, specific conductance, temperature, and pH of water from springs in the Dickson area.

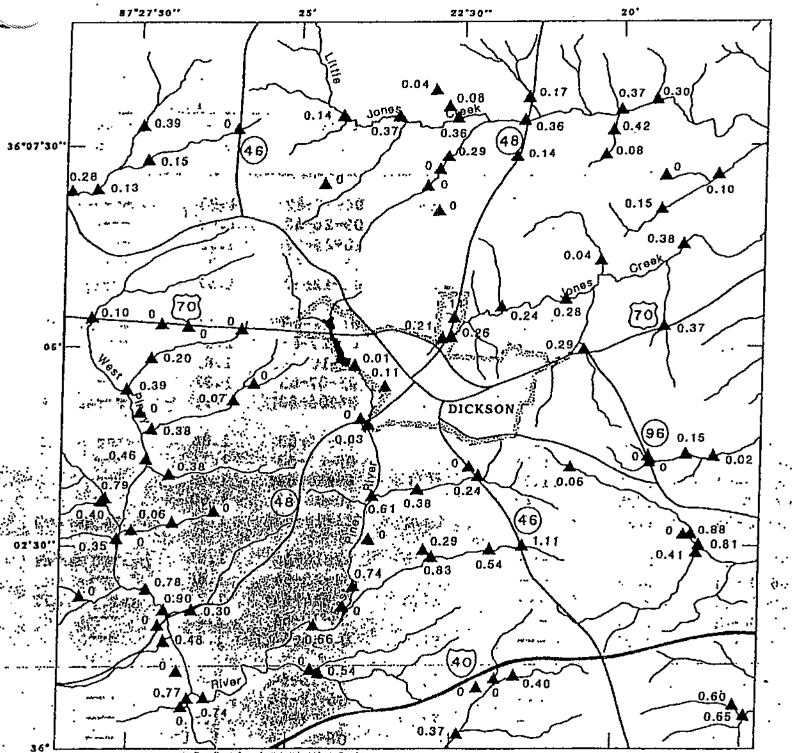
Spring (fig. 12)	Date	Discharge (ft^3/s)	Specific conductance (μmho/cm 25°C)	Temperature (°C)	pH
Walnut Grove Spring	7-11-79	0.05*	245	16.5	7.4
	7-19-79	0.04*	270	16.0	---
Donegan Spring	7-11-79	0.84	270	17.0	7.0
Redden Spring	7-11-79	0.57	220	15.5	7.5
	7-19-79	0.68	230	15.5	---
Fielder Spring	7-11-79	1.78	255	14.5	7.6
Bruce Spring	7-11-79	1.42	240	15.5	7.7
	7- 7-79	1.34	175	14.0	---
Grassy Spring	7-19-79	0.07	---	---	---
Payne Spring	9-29-78	0.20	---	---	---
Tice Spring	9-17-80	0.16	280	14.0	---
	12-22-80	0.13	260	13.0	---
	1-12-81	0.17	280	13.0	---
	2- 2-81	0.18	290	14.0	---
	2-23-81	0.22	270	13.0	---
	4-13-81	0.28	250	14.5	---
	5-21-81	0.79	190	13.0	---
	6-29-81	0.21	295	14.5	---

* Estimated.

Table 2.--Discharge measurements - Fielder Spring and Spring

Date	Discharge (ft^3/s) Fielder Spring	Bruce Spring	Date	Discharge (ft^3/s) Fielder Spring	Bruce Spring
08-06-31	2.06	1.30	08-29-62	1.93	---
09-29-31	1.72	1.10	09-26-62	1.98	---
07-17-52	2.17	1.68	10-25-62	1.93	---
08-12-52	1.90	1.19	11-28-62	1.78	---
09-23-52	1.86	1.19	01-12-62	1.57	---
10-22-52	2.02	1.12	01-12-63	1.46	---
11-20-52	1.72	1.17	03-27-63	2.01	---
12-08-52	1.62	1.00	04-10-63	1.85	---
01-20-53	1.74	1.08	05-07-63	1.92	---
02-24-53	1.98	1.54	06-05-63	1.91	---
03-18-53	2.18	1.67	07-12-63	1.86	---
04-29-53	1.95	1.46	08-05-63	1.74	---
05-26-53	2.21	1.75	09-10-63	1.78	---
06-23-53	2.09	1.45	10-03-63	1.60	---
06-02-54	1.94	1.31	11-13-63	1.53	---
07-07-61	2.96	---	12-10-63	1.66	---
08-09-61	3.12	---	01-23-64	1.86	---
09-07-61	2.09	---	02-14-64	1.75	---
10-04-61	2.07	---	03-10-64	2.25	---
11-02-61	1.83	---	04-16-64	1.85	---
12-04-61	1.58	---	05-15-64	2.67	---
01-02-62	1.79	---	06-18-64	1.96	---
02-07-62	2.03	---	07-16-64	1.65	---
03-06-62	2.70	---	08-20-64	1.71	---
04-03-62	3.03	---	09-23-64	1.78	---
05-02-62	2.58	---	10-15-64	1.70	---
05-03-62	2.38	---	11-17-64	1.50	---
07-03-62	2.23	---	07-11-79	1.78	1.42
08-02-62	2.30	---	07-19-79	---	1.34

	Mean	Maximum	Minimum
Fielder Spring	1.98	3.12	1.46
Bruce Spring	1.34	1.75	1.00



Base from U.S. Geological Survey, 1:24,000 quadrangles: Burns(1953), Charlotte(1958), Dickson(1953), and Vanleer(1958)

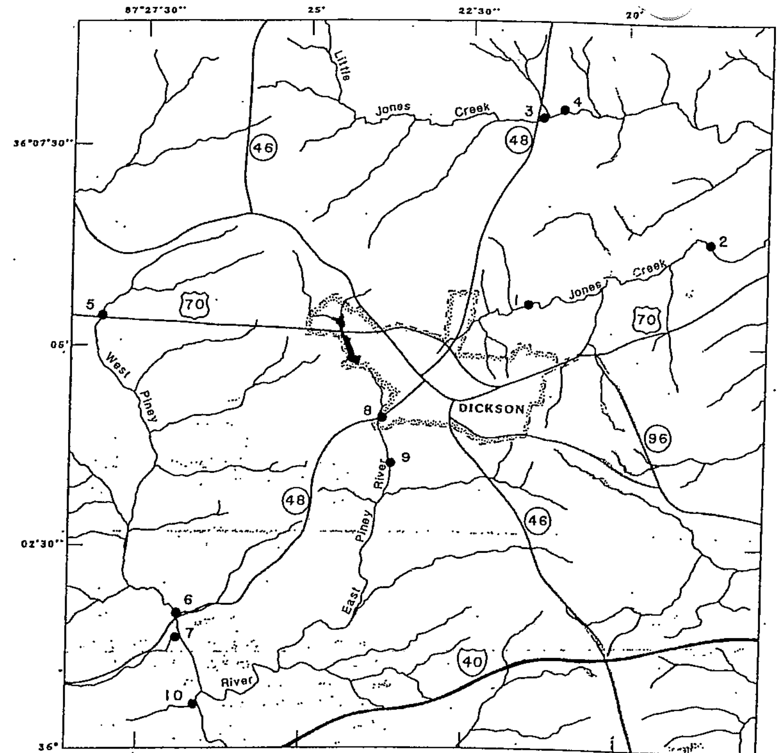
4000 0 4000 8000 FEET

1000 0 1000 2000 METERS

EXPLANATION

0.26 ▲ Measurement site and discharge, in cubic feet per second per square mile

Figure 13.— Discharge measurements in the Dickson area.



Base from U.S. Geological Survey, 1:24,000 quadrangles: Burns(1953), Charlotte(1958), Dickson(1953), and Vanleer(1958)

4000 0 4000 8000 FEET

1000 0 1000 2000 METERS

EXPLANATION

●4 Low-flow site and reference number (See table 3)

Figure 14.— Low-flow sites in the Dickson area.

Table 3.--Low-flow discharge measurements for streams in the study area

Reference no. (fig. 14)	Station no.	Drainage area (mi^2)	Date	Discharge (ft^3/s)	Date	Discharge (ft^3/s)
1	03434585	5.05	10-17-50	0.42	06-24-52	0.57
2	03434590	13.3	07-31-74	2.20	08-21-75	1.8
3	03434593	10.9	07-07-50	3.47		
4	03434595	13.8	09-12-51	0.57		
5	06302170	2.16	10-10-61	0	09-27-63	0.05
			05-15-62	0.56	10-04-64	0
			04-25-63	0.45	08-06-65	0.36
6	03602192	21.2	07-07-50	12.5	05-15-62	22.0
			09-12-51	9.01	04-25-63	17.7
			10-17-51	8.75	09-27-63	9.95
			06-24-52	10.6	10-04-64	9.11
			10-10-61	8.01	08-10-65	12.6
7	03602193	1.95	11-13-52	0		
8	03602196	2.90	10-24-54	0.47		
9	03602200	6.21	10-10-61	1.67	10-04-64	2.38
			05-15-62	5.50	08-10-65	5.57
			04-25-63	4.88	09-03-69	3.16
			09-27-63	2.61		
10	03602210	0.73	11-13-52	0		

Data from Gold, 1980.

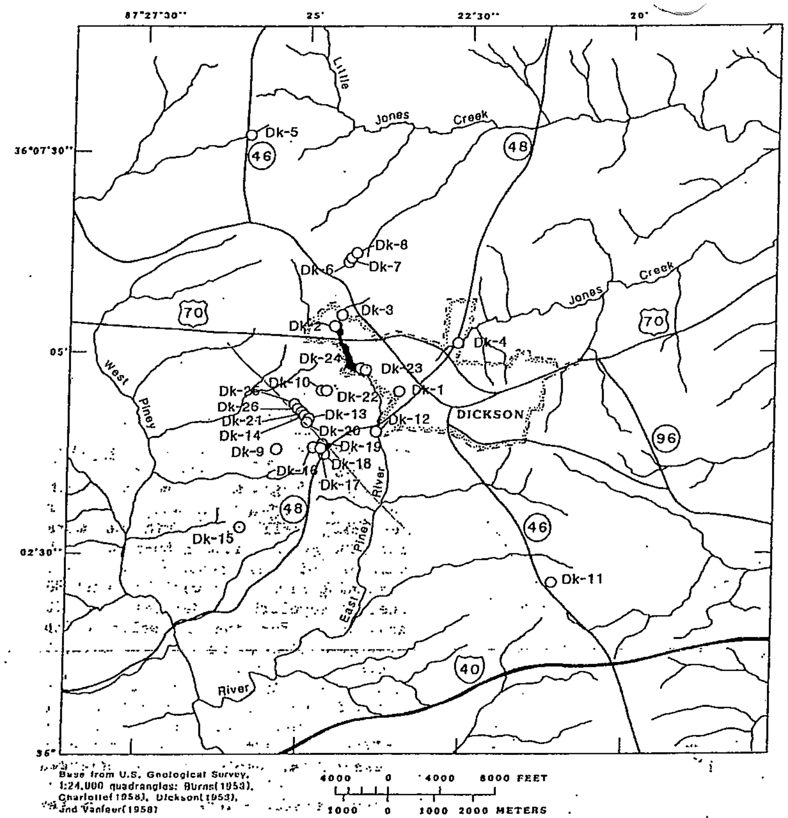
By using low-flow data, the minimum amount of recharge to the ground-water system in the Dickson area can be estimated. Discharge data from the gaging station on the Piney River at Vernon, Tenn., south of the study area, were used for this purpose. During 1980, the minimum discharge of the Piney River at Vernon was 90 ft^3/s. At this site, the Piney is draining 202 square miles. While part of this drainage basin is outside of the study area, it is assumed that the recharge rate for the entire basin is about the same as the recharge rate in the Dickson area.

Assuming that the 90 ft^3/s represents the amount of ground water being discharged to streams and springs, then about 320 acre-feet of water must recharge each square mile annually. This represents a minimum rate of about 6 inches of the annual precipitation that is recharging the ground-water system around Dickson.

RESULTS OF DRILLING

Test Well Data

Twenty-six wells were drilled during the study (fig. 15). Well depths ranged from 21 to 400 feet, and the wells were cased to depths ranging from



EXPLANATION

Dk-4 ○ Test well and field number (See table 4)

Figure 15.— Test wells.

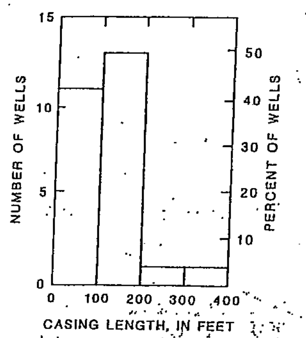


Figure 16.--Frequency distribution of casing lengths in the test wells.

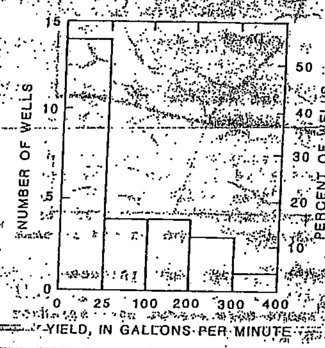


Figure 17.--Frequency distribution of the yields of the test wells while blowing with compressed air.

5 to 317 feet below land surface (fig. 16). Regolith thickness ranged from 4 feet in the valleys to 331 feet in the uplands. Yields during drilling were less than 1 to more than 300 gal/min; only two wells were dry (table 4). Eight wells yielded more than 100 gal/min (fig. 17). Data from the test wells are summarized in table 4.

The regolith at the 26 test wells ranged from 4 to 331 feet thick (table 4) with an average thickness of 88 feet. Fourteen wells penetrated at least 80 feet of regolith and 10 of these wells had fine-grained beds of limestone near the top of rock. Of these 14 wells, 7 (all with fine-grained limestone near the top of rock) yielded 80 gal/min or more from solution openings in bedrock, and 2 wells yielded more than 100 gal/min from the regolith (fig. 18). Well Dk-9 yielded 175 gal/min from an 8-foot layer of chert gravel at the top of bedrock. Well Dk-15 yielded more than 300 gal/min from a 60-foot thick section of calcareous sand. The remaining five wells with at least 80 feet of regolith yielded less than 20 gal/min. For the 12 wells which have less than 80 feet of regolith, 9 yielded less than 20 gal/min. The three remaining wells, all with fine-grained beds of limestone near the top of rock, yielded 30 to 50 gal/min; however, the yield of one of these wells, Dk-24, may be affected by the presence of the city lake which causes local ground-water levels to remain high.

The regolith thickness was highly variable within short lateral distances. For example, wells Dk-17, Dk-18, and Dk-19 are within 200 feet of each other and have regolith thicknesses of 90, 110, and 70 feet, respectively. Well Dk-9 has 331 feet of regolith whereas two domestic wells within about 400 feet of Dk-9

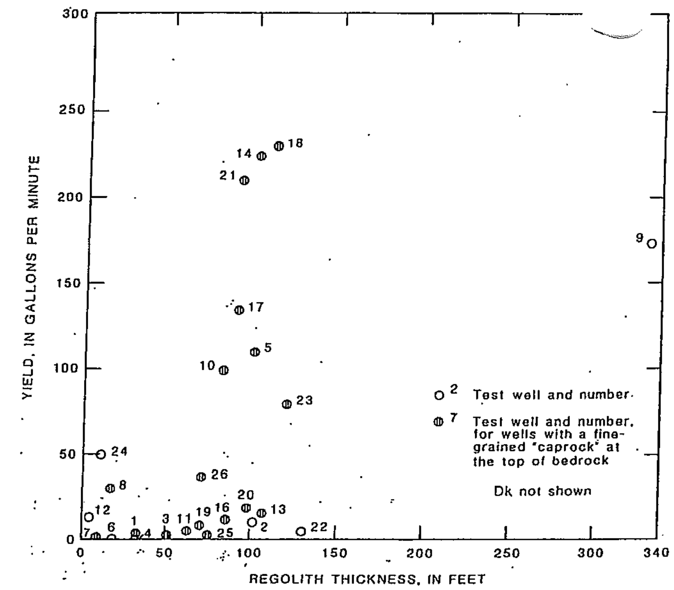


Figure 18.--Regolith thickness versus yield for test wells.

have reported regolith thicknesses of 98 and 160 feet. Well Dk-23 has approximately 120 feet of regolith and well Dk-24 which is 230 feet away has only 10 feet of regolith. These variations in regolith thickness indicate that the bedrock surface is irregular and may be pinnacled. The analysis of the regolith thickness and yield showed that wells are likely to produce more water in areas of thick regolith.

The primary water-bearing zones are solution openings in the Warsaw Limestone and to some extent in the Fort Payne Formation. The regolith consisted of dense clay and, with two exceptions, yielded very little water. The size of solution openings penetrated during drilling ranged from less than 1 foot to more than 40 feet thick. Generally, the smaller openings were clean, water-bearing zones whereas the larger openings, more than 10 feet, were partially or almost completely filled with clay. Solution openings which occurred below fine-grained "cap rock" near the top of bedrock were more likely to yield large

Table 4.--Test well data and water occurrence

Well no. Field	Well no. Office	Latitude	Longitude	Date Completed	Altitude (ft)	Total depth (ft)	Regolith thickness (ft)	Depth cased (ft)	Water bearing zones, depth (ft)	Final yield by blowing (gal/min)	Water level below land surface (ft)	Water bearing formation*	Finish	Remarks
Dk-1	Di:F-60	36°04'24"	87°23'36"	Nov. 14, 1978	780	400	31	32	56-59 155	3	---	W,FP	Open	In the final yield the hole was losing air to an adjacent well.
Dk-2	Di:F-61	36°05'20"	87°24'35"	Nov. 17, 1978	810	300	100	101	107-109	11	---	W	Open	
Dk-3	Di:F-62	36°05'28"	87°24'30"	Nov. 21, 1978	810	180	45	91	61-65	2	---	W	Destroyed	Casing was leaking.
Dk-4	Di:F-63	36°05'04"	87°22'43"	June 23, 1980	710	222	31	40.5	70	0.5	---	FP	Destroyed	
Dk-5	Di:K-8	36°07'40"	87°25'59"	June 26, 1980	850	400	100	104.8	111-112 113-136 178-179 270-271	110	40.40	W,FP	Open	Hydrogen sulfide was encountered at 270-271 feet.
Dk-6	Di:F-64	36°06'09"	87°24'24"	June 26, 1980	800	21	18	20	None	Dry	---		Destroyed	Well destroyed; hole was slanted.
Dk-7	Di:F-65	36°06'12"	87°24'23"	June 27, 1980	800	240	9	20	None	Dry	---		Destroyed	
Dk-8	Di:F-66	36°06'14"	87°24'19"	June 28, 1980	795	206	16	20	160 180 205-206	30	15.30	FP	Open	The zone at 205-206 feet produced water containing hydrogen sulfide.
Dk-9	Di:F-67	36°03'42"	87°25'28"	July 2, 1980	815	340	331	317	323-331	175	63.70	R	Open	
Dk-10	Di:F-68	36°04'30"	87°24'43"	July 7, 1980	820	280	82	127	100-110 123-131	100	35.20	W	Open	
Dk-11	Di:G-86	36°02'08"	87°21'11"	July 9, 1980	850	400	62	70	295 370	5	55.75	W	Open	
Dk-12	Di:F-69	36°03'59"	87°23'56"	July 9, 1980	710	160	4	5	25 34 116	13	5.45	FP	Destroyed	
Dk-13	Di:F-70	36°04'08"	87°24'54"	July 11, 1980	855	320	106	162	124 225 245-250	15	58.50	W	Open	About 550 feet from Dk-21.
Dk-14	Di:F-71	36°04'11"	87°25'00"	July 14, 1980	845	280	100	126	100-105 139-143	225	60.50	W	Open	330 feet from Dk-21.
Dk-15	Di:F-72	36°02'51"	87°26'00"	July 28, 1980	760	300	300	260	200-260 270-285 287-292	300+	41.26	R	Open	Yields water from sand within the open

Table 4.--Test well data and water occurrence--Continued

Well no. Field	Well no. Office	Latitude	Longitude	Date Completed	Altitude (ft)	Total depth (ft)	Regolith thickness (ft)	Depth cased (ft)	Water bearing zones, depth (ft)	Final yield by blowing (gal/min)	Water level below land surface (ft)	Water bearing formation*	Finish	Remarks
Dk-16	Di:F-73	36°03'49"	87°24'56"	July 29, 1980	815	350	84	114	92 102-105 140 300 307	12	54.48	W,FP	Open	About 700 feet from Dk-17.
Dk-17	Di:F-74	36°03'48"	87°24'47"	Aug. 1, 1980	820	300	90	170	89-100 113-116 130-140 178-181	135	59.1	W	Open	The upper 3 zones were cased off due to air bubbling up around the casing when cased to 144 feet.
Dk-18	Di:F-75	36°03'46"	87°24'45"	Oct. 2, 1980	820	250	110	180	165-168	230	66.47	W	Open	200 feet from Dk-17.
Dk-19	Di:F-76	36°03'50"	87°24'46"	Oct. 4, 1980	820	300	70	101	87 150 251-252	8	69.72	W	Open	190 feet from Dk-17.
Dk-20	Di:F-77	36°04'07"	87°25'01"	Oct. 6, 1980	860	250	98	104	117-121 130-135	18	76.81	W	Open	515 feet from Dk-21.
Dk-21	Di:F-78	36°04'12"	87°25'04"	Oct. 8, 1980	840	160	90	104	95-97 126-143	210	68.25	W	Open	
Dk-22	Di:F-80	36°04'31"	87°24'39"	Dec. 1, 1980	820	300	130	134	150	5		W	Open	About 230 feet from Dk-10.
Dk-23	Di:F-81	36°04'46"	87°24'08"	Jan. 8, 1981	750	240	120	124	112 150	80	18.14	W	Open	
Dk-24	Di:F-82	36°04'47"	87°24'11"	Jan. 14, 1981	750	200	10	20	8 135-149	50	5.9	W	Open	215 feet from Dk-23.
Dk-25	Di:F-83	36°04'20"	87°25'11"	May 5, 1981	810	220	75	82	47 97 121-124	4	23.56	W	Open	About 1,150 feet from Dk-21.
Dk-26	Di:F-84	36°04'11"	87°25'07"	May 7, 1981	820	250	70	79	104 132 234	37	38.05	W	Open	About 600 feet from Dk-21.

* R - Regolith
W - Warsaw Limestone
FP - Fort Payne Formation

unts of water. This "cap rock" is a fine-grained siliceous limestone or omite which allowed for the development of solution openings by inhibiting the downward weathering and movement of clay into the solution openings. The size and number of solution openings decreased with depth.

Specific Capacity Tests

Specific capacity tests were conducted on 10 wells. Specific capacity is the discharge of a well expressed as a rate of yield per unit of drawdown and can be used as an indicator of the capacity of the well and aquifer. Average yield for the individual wells during the tests ranged from about 72 gal/min in Dk-24 to 300 gal/min in Dk-15. Specific capacities for the wells ranged from 0.71 to 12.7 gallons per minute per foot [(gal/min)/ft] of drawdown (table 5) and averaged 4.10 (gal/min)/ft. A high specific capacity, such as 12.7 (gal/min)/ft in Dk-21, indicates that the water-bearing zone supplying the well is capable of transmitting ground water more readily than a well with a lower specific capacity, such as 0.71 (gal/min)/ft in Dk-24.

Table 5.--Specific-capacity test data

Well no. Yield	Well no. Office	Date of test	Static water level below measuring point (ft)	Draw-down (ft)	Average yield during test (gal/min)	Specific capacity [(gal/min)/ft]	Length of test (h)	Remarks
Dk-5	Di:K-8	6/26/80	49.50	47.35	110	2.32	2.0	Slow and incomplete recovery.
Dk-9	Di:F-67	7/ 2/80	73.10	128.7	175	1.36	1.0	Yields water from regolith.
Dk-10	Di:F-68	7/ 7/80	48.45	54.05	100	1.85	2.0	
Dk-14	Di:F-71	7/14/80	63.07	27.74	225	8.11	1.5	
Dk-15	Di:F-72	7/28/80	51.64	87.89	300	3.41	2.0	Yields water from regolith.
Dk-17	Di:F-74	8/ 1/80	70.77	36.44	135	3.70	2.0	
Dk-18	Di:F-75	10/ 2/80	83.14	46.62	270	5.79	1.5	
Dk-21	Di:F-78	10/ 8/80	70.50	16.53	210	12.7	4.0	
Dk-23	Di:F-81	1/22/81	3.84	83.13	85	1.02	6.4	
Dk-24	Di:F-82	1/13/81	19.42	100.75	72	0.71	4.0	

YIELD-SPECIFIC CAPACITY TESTS

Tests at the Dk-17 Site

Two tests were conducted at the Dk-17 site. A 72-hour test took place in November 1980, and an 8-hour test was conducted in August 1981. Well Dk-17 was pumped during both tests, and water levels were measured at four observation wells. Wells Dk-16, Dk-18, and Dk-19 are 850, 200, and 190 feet, respectively, from the pumped well. Di:F-27 is a domestic well about 415 feet from Dk-17 (fig. 19).

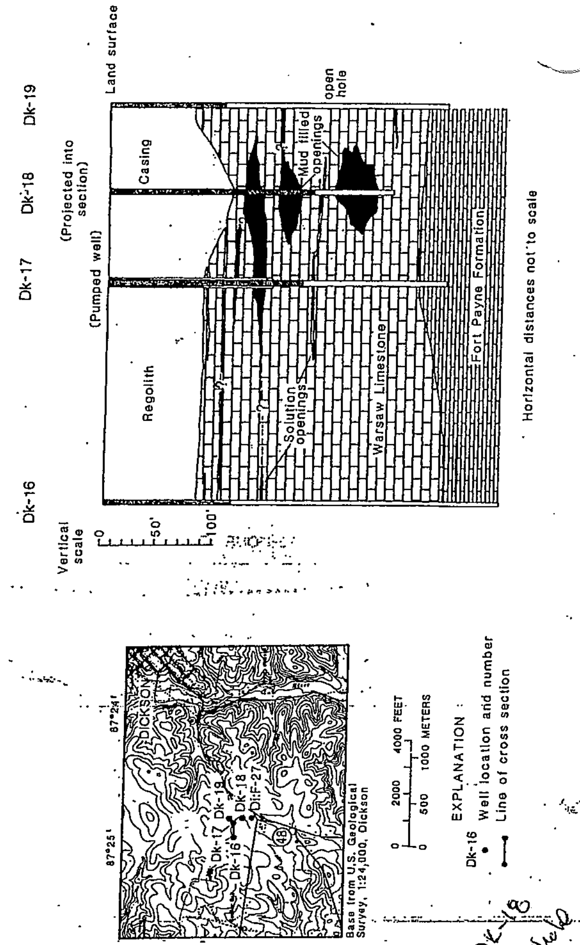


Figure 19.-- Geologic cross section of the Dk-17 site with location map.

Pumped Dk-18 created sinkhole during drawdown

The test site is underlain by the St. Louis Limestone, Warsaw Limestone, and Fort Payne Formation. The St. Louis Limestone and the upper part of the Warsaw Limestone have weathered to a clay regolith approximately 90 feet thick (fig. 19). Ground water occurs in solution openings in the Warsaw Limestone and at the contact with the Fort Payne Formation. Many openings penetrated by Dk-17 and Dk-18 were partially or completely filled with clay.

The test began on November 19, 1980, and ended November 22, 1980, after 3 days of pumping. The initial pumping rate was approximately 140 gal/min. Water levels in the observation wells responded to pumping Dk-17 in various degrees (fig. 20). The specific capacity of Dk-17 at the end of the first step was 3.0 (gal/min)/ft of drawdown. At the end of the test, the specific capacity had decreased to 1.8 (gal/min)/ft of drawdown for an average pumping rate of 155 gal/min. The decrease in specific capacity may reflect well losses caused by lower water levels or possible dewatering of some upper water-bearing zones. Water levels in Dk-19 began to rise before pumping stopped. This could occur if the connection between Dk-19 and Dk-17 became blocked. Drawdown in Dk-17 and the observation wells is summarized in table 6. Data from this test were analyzed using a mathematical model, but the results were inconclusive. Because of this, the response of the well to higher pumping rates or to a longer pumping period could not be determined.

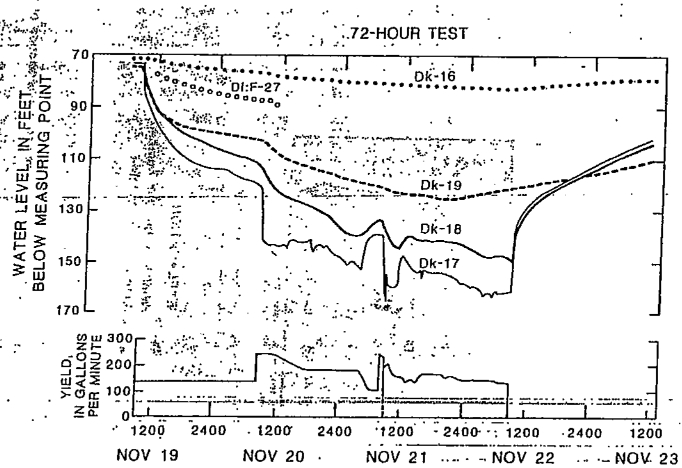


Figure 20.-- Hydrograph and yield of 72-hour test at Dk-17.

Table 6.--Drawdown and recovery in wells at the Dk-17 site during the 72-hour test

	Well no.				
	Dk-17 (pumped well)	Dk-16	Dk-18	Dk-19	Di:F-27
Distance from pumped well, in feet.	--	850	200	190	415
Prepumping water level, in feet below measuring point.	73.49	71.71	74.44	74.80	74 (est)
Drawdown at end of first step, in feet.	46.78	5.20	38.10	27.95	13.6
Drawdown at the end of test, in feet.	87.51	10.68	74.66	46.23	--
Recovery 2 hours after pumping stopped, in feet.	27.51	0.09	14.04	0.89	--

A plot of drawdown versus distance from the pumped well (fig. 21) was used to determine if the observation wells are connected with the water-bearing zones in Dk-17. For observation wells in an aquifer with uniform properties, this type of plot would ideally show a straight line near the pumped well and a smooth curve at the distant observation wells. The slope of curves between Dk-17 and Dk-18 is relatively constant which indicates that these wells have a good hydraulic connection. At times (t = 1,800 and 4,200 minutes) the slope is steeper than earlier in the test. Steepening of the slope may be due to possible dewatering of the aquifer or well entrance losses.

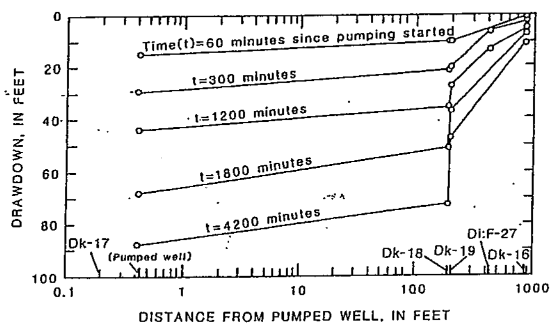


Figure 21.-- Drawdown versus distance from the pumped well for the 72-hour test of Dk-17.

The abrupt changes in slope between Dk-18 and the other wells as time increases indicates that these wells did not penetrate the same water-bearing zone as Dk-17 and Dk-18. The water level in well Di:F-27 was drawn down below the bottom of the well at about 90 feet on November 20 and no further data could be collected. Because the water levels in Di:F-27, Dk-16 and Dk-19 respond to pumping in Dk-17, there is some hydraulic connection with the zone penetrated by Dk-17 and Dk-18.

A caliper log of Dk-17 revealed a large opening at the bottom of the 10-inch casing. This opening was believed to be connected to a water-bearing zone at 130 to 140 feet which caused turbidity by allowing clay to enter the well. During (June or July) 1981, an 8-inch casing was installed to a depth of 170 feet in an effort to seal this opening.

On August 14, 1981, Dk-17 was pumped at a constant rate of 120 gal/min for 8 hours. Wells Dk-18 and Dk-19 were used as observation wells (fig. 22). At the end of the test there was 20.86 feet of drawdown, for a specific capacity of 5.75 (gal/min)/ft. During the 72-hour test, well Dk-17 had a specific capacity of 3.80 (gal/min)/ft of drawdown after 8 hours. The improvement could be due to the development of the water-bearing zone at 180 feet.

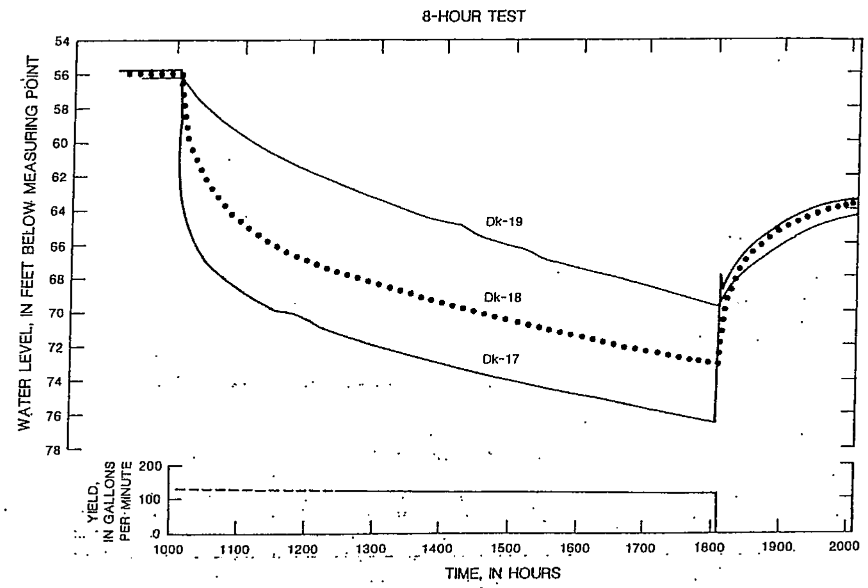


Figure 22.— Hydrograph and yield for the 8-hour test at Dk-17.

The response of water levels in Dk-18 and Dk-19 are similar to the response during the 72-hour test (fig. 22). Water levels in well Dk-19 showed a much more rapid rate of recovery following the 8-hour test (table 7). It is possible that the connection between Dk-17 and Dk-19 was blocked at the end of the 72-hour test. This could have caused the rise in water level in Dk-19 before pumping stopped during the 72-hour test as well as the slow recovery.

Table 7.--Drawdown and recovery in Dk-17, Dk-18 and Dk-19 during the 8-hour test

	Well no.		
	Dk-17 (pumped well)	Dk-18	Dk-19
Prepumping water level, in feet below measuring point.	55.8	56.00	55.71
Drawdown after 4 hours, in feet.	17.24	13.65	9.23
Drawdown at end of test, in feet.	20.86	17.12	13.44
Recovery 1 hour after pumping stopped, in feet.	11.94	8.12	3.89

Test at the Dk-21 Site

Well Dk-21 was pumped at an average rate of 350 gal/min during a 72-hour aquifer test begun on December 15, 1980. Wells Dk-13, Dk-14 and Dk-20 were within 500 feet of Dk-21 and were used as observation wells. Dk-25 and Dk-26 are also located near the site (fig. 23) but had not been drilled at the time of the test.

The wells at this site began in the lower part of the St. Louis Limestone which, along with the upper part of the Warsaw Limestone, has weathered to form a clay regolith with some scattered chert gravel (fig. 23). The primary water-bearing zone in Dk-21 is a 17-foot high solution opening in the Warsaw Limestone. The opening thins to 4 feet in Dk-14.

The initial rate of pumping was 430 gal/min. Figure 24 shows the response of water levels in the pumping well Dk-21 and the observation wells Dk-13, Dk-14, and Dk-20. When pumping stopped on December 18, water levels in Dk-14 and Dk-21 recovered rapidly. Water levels in wells Dk-13 and Dk-20 responded slowly to the end of pumping (table 8). Specific capacity at the end of the 1,530 minute step was 8.6 (gal/min)/ft of drawdown at 430 gal/min. At the end of the test, specific capacity was approximately the same at 8.8 (gal/min)/ft of drawdown with an average pumping rate of 350 gal/min. This aquifer test was also analyzed and again the results were inconclusive. The response of this well to longer periods of pumping or to a higher rate of pumping could not be determined.

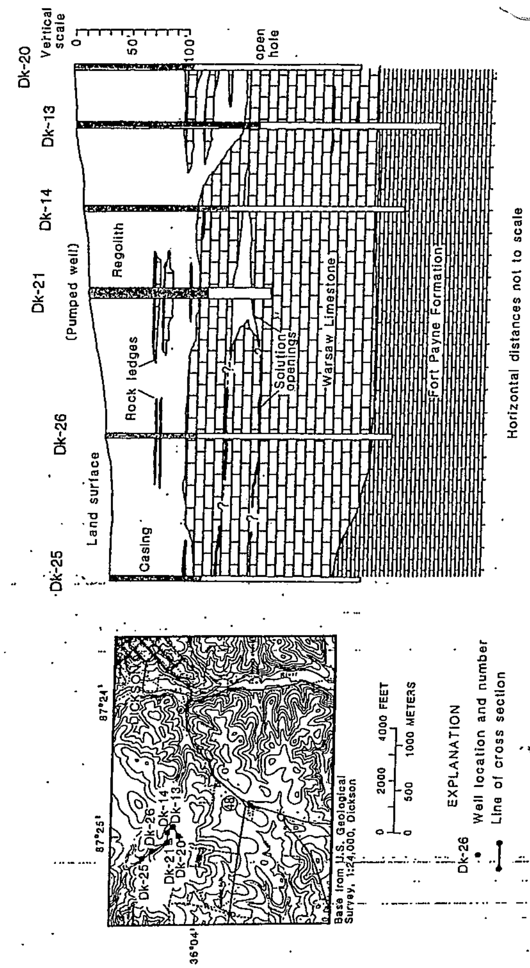


Figure 23.-- Geologic cross section at the Dk-21 site with location map.

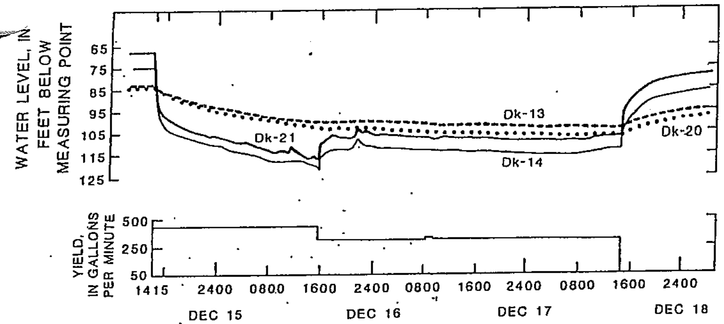


Figure 24.-- Hydrograph and yield during the 72-hour test of well Dk-21.

Table 8.--Drawdown and recovery in wells Dk-13, Dk-14, Dk-20, and Dk-21 during the 72-hour test

	Well no.			
	Dk-21 (pumped well)	Dk-13	Dk-14	Dk-20
Distance from pumped well, in feet.		552	330	515
Prepumping water level, in feet below measuring point.	65.43	81.13	76.65	82.29
Drawdown at end of first step, in feet.	49.97	17.65	46.96	19.13
Drawdown at end of test, in feet.	39.77	20.52	38.76	23.04
Recovery 200 minutes after pumping stopped, in feet.	21.29	2.94	20.28	2.55

The response of the water levels in Dk-13 and Dk-20 in[illegible]s that the water-bearing zone in Dk-21 and Dk-14 is poorly connected with other zones in Dk-13 and Dk-20. A graph of drawdown versus distance from the pumped well (fig. 25) shows the shape of the cone of depression during pumping. The abrupt change in the slope between Dk-14 and Dk-20 supports the assumption that wells Dk-13 and Dk-20 are open to different water-bearing zones than the main zone in Dk-14 and Dk-21. Because water levels in Dk-20 and Dk-13 respond to pumping in Dk-21, there must be some hydraulic connection between these two wells and the main water-bearing zone.

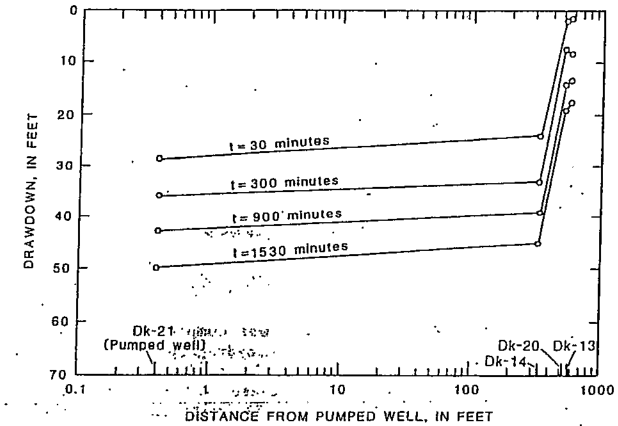


Figure 25.-- Drawdown versus distance from the pumped well for the test of Dk-21.

ADDITIONAL DRILLING NEAR THE DK-21 SITE

Following the 72-hour test, two additional wells, Dk-25 and Dk-26, were drilled in an attempt to determine the lateral extent of the primary water-bearing zone in Dk-21. Well Dk-25 was drilled to a depth of 220 feet. The final yield was 4 gal/min while blowing with compressed air for 15 minutes. Water levels at Dk-14 did not respond to drilling Dk-25 (fig. 26). However, the small yield from Dk-25 and short pumping time would not be expected to effect water levels in Dk-14 which is more than 1,400 feet away.

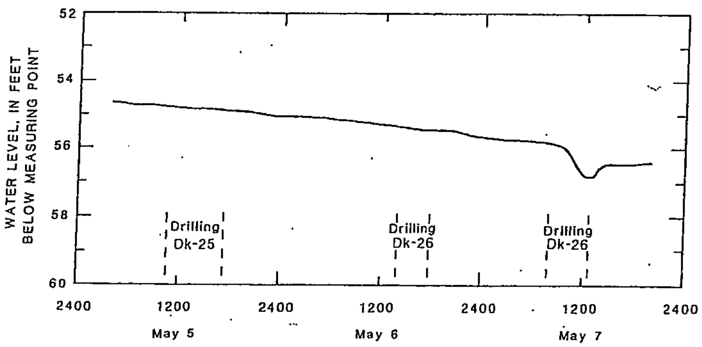


Figure 26.-- Hydrograph for well Dk-14 during May 5-7, 1981.

Well Dk-26, about 900 feet from Dk-14, was completed to a depth of 250 feet. The final yield was 37 gal/min. The hydrograph of Dk-14 (fig. 26) shows an abrupt drop in water level during the drilling of Dk-26 on May 7 indicating a hydraulic connection between these wells. The water-bearing zones at 104 and 132 feet in Dk-26 may correlate with the main water-bearing zone in Dk-21 and Dk-14 (fig. 23).

WATER QUALITY

Specific conductance of ground water from the test wells ranged from 200 to more than 1,500 micromhos per centimeter (µmhos/cm). Most values were between 250 and 350 µmhos/cm (table 9). Generally, the specific conductance increased with depth.

Ground water from the regolith (Dk-9 and Dk-15) and from solution openings in the Warsaw Limestone, such as in Dk-14, Dk-17 and Dk-21, had a specific conductance ranging from 200 to about 400 µmhos/cm. Wells which penetrated solution openings in the Fort Payne Formation (Dk-16 and Dk-26) generally had values within this range. However, in wells Dk-1, Dk-5, and Dk-8, hydrogen sulfide was detected in water from openings in the Fort Payne Formation. After the detection of hydrogen sulfide, the specific conductance ranged from 800 to as much as 1,550 µmhos/cm.

Table 9.--Specific conductance of water from the t[illegible]lls

Well no.	Depth of well at time of sampling (feet)	Specific conductance (µmho/cm at 25°C)	Well no.	Depth of well at time of sampling (feet)	Specific conductance (µmho/cm at 25°C)
Dk-1	400	850	Dk-15	250	300
				260	300
Dk-2	300	360		290	320
				300	340
Dk-5	110	400			
	120	425	Dk-16	350	320
	210	450			
	265	560	Dk-17	116	270
	270	775		135	400
	300	1,475		145	335
	320	1,550		180	300
	340	1,475		190	300
	390	1,200		200	290
	400	1,400		240	300
				260	305
Dk-8	206	800		275	300
				290	300
Dk-9	315	280			
	330	275	Dk-18	168	290
	340	320		173	300
				211	255
Dk-10	280	320		250	320
Dk-14	156	220	Dk-21	130	280
	180	200			
	270	320	Dk-22	270	330
			Dk-25	220	350
			Dk-26	140	425
				180	420
				220	390
				250	390

Ground water from wells Dk-17 and Dk-21 tapping the Warsaw Limestone was analyzed for 54 parameters. These analyses show no major water-quality problems (table 10). Water from both wells is a hard, calcium bicarbonate type with similar proportions of major mineral constituents (fig. 27). By comparison, well Fv-13 in Fairview, Tenn., yields mineralized water from the Fort Payne Formation. Hydrogen sulfide was also detected in this well, the water type is believed to be similar with water from the Fort Payne in wells Dk-1, Dk-5, and Dk-8.

Table 10.--Analyses of water from Dk-17 and Dk-21 compared with standards for maximum levels of constituents in finished drinking water

Constituent or property	Well nos. Dk-17	Well nos. Dk-21	Tennessee standards for public water supplies[1]: Secondary maximum contaminant level	Tennessee standards for public water supplies[1]: Maximum contaminant level	National drinking-water regulations: Secondary maximum contaminant level[2]	National drinking-water regulations: Primary maximum contaminant level[3]
Alkalinity, total (mg/L as $CaCO_3$)	140	130	--	--	--	--
Aluminum, dissolved (μg/L as Al)	--	100	--	--	--	--
Arsenic, dissolved (μg/L as As)	0	1	--	50	--	50
Barium, dissolved (μg/L as Ba)	30	20	--	1,000	--	1,000
Beryllium, dissolved (μg/L as Be)	0	0	--	--	--	--
Boron, dissolved (μg/L as B)	2	--	--	--	--	--
Cadmium, dissolved (μg/L as Cd)	2	1	--	10	--	10
Calcium, dissolved (Ca in mg/L)	48	41	--	--	--	--
Carbon, dissolved organics (mg/L as C)	--	0.7	--	--	--	--
Carbon, total organic (mg/L as C)	2.9	--	--	--	--	--
Chloride, dissolved (mg/L as Cl)	2.5	1.2	250	--	250	--
Chromium, dissolved (μg/L as Cr)	10	10	--	50	--	50
Cobalt, dissolved (μg/L as Co)	3	7	--	--	--	--
Color (platinum cobalt units)	0	2	15	--	15	--
Copper, dissolved (μg/L as Cu)	21	5	1,000	--	1,000	--
Cyanide, dissolved (mg/L as CN)	0.00	0.00	--	--	--	--
Detergents, MBAS (mg/L)	--	0.0	0.5	--	0.5	--
Dissolved solids, residue at 180°C (mg/L)	170	--	500	--	500	--
Fluoride, dissolved (mg/L as F)	0.1	0.1	1.3	2.0	--	1.8[4]
Hardness, noncarbonate (mg/L as $CaCO_3$)	0	0	--	--	--	--
Hardness, total (mg/L as $CaCO_3$)	140	130	--	--	--	--
Iron, dissolved (μg/L as Fe)	50	0	300	--	300	--
Iron, total (μg/L as Fe)	--	0.43	300	--	300	--
Lead, dissolved (μg/L as Pb)	2	2	--	50	--	50
Lithium, dissolved (μg/L as Li)	2	0	--	--	--	--
Magnesium, dissolved (mg/L as Mg)	4.4	6.2	--	--	--	--
Manganese, dissolved (μg/L as Mn)	8	1	50	--	50	--
Manganese, total (μg/L as Mn)	--	20	50	--	50	--
Mercury, dissolved (μg/L as Hg)	0.1	0.2	--	2	--	2
Molybdenum, dissolved (μg/L as Mo)	--	0	--	--	--	--
Nickel, dissolved (μg/L as Ni)	2	2	--	--	--	--
Nitrate, dissolved (mg/L as N)	0.87	0.18	--	10	--	10
Nitrite, dissolved (mg/L as N)	0.00	0.01	--	--	--	--
Nitrogen, total (mg/L as N)	0.87	0.19	--	--	--	--
pH (units)	8.5	7.9	6.5-8.5	--	6.5-8.5	--
Phenols (μg/L)	0	4	--	--	--	--
Phosphate, dissolved (mg/L as P)	0.04	0.03	--	--	--	--
Potassium, dissolved (mg/L as K)	0.5	0.4	--	--	--	--
Selenium, dissolved (μg/L as Se)	0	0	--	10	--	10
Silica, dissolved (mg/L as SiO_2)	9.4	7.6	--	--	--	--
Silver, dissolved (μg/L as Ag)	0	0	--	50	--	50
Sodium, dissolved (mg/L as Na)	3.6	1.7	--	--	--	--
Sodium adsorption ratio	0.1	0.1	--	--	--	--
Sodium percent	5	3	--	--	--	--
Specific conductivity (μmhos/cm at 25°C)	284	267	--	--	--	--
Strontium, dissolved (μg/L as Sr)	120	60	--	--	--	--
Sulfate, dissolved (mg/L as SO_4)	4.5	2.9	250	--	250	--
Turbidity (NTU)	0.40	2.4	--	1	--	1 5
Temperature (°C)	14.0	13.5	--	--	--	--
Zinc, dissolved (μg/L as Zn)	10	30	5,000	--	5,000	--
Coliform, total, immed. (Cols./100 mL)	40	2	--	4 6	--	4 6
Coliform, fecal, 0.45 UM-MF (Cols./100 mL)	1	2	--	4 6	--	4 6
Streptococci, fecal, (Cols./100 mL)	1	1	--	4 6	--	4 6

1 Tennessee Department of Public Health, 1977.
2 U.S. Environmental Protection Agency, 1979.
3 U.S. Environmental Protection Agency, 1976.
4 Based on annual average maximum daily temperatures.
5 A value of five or fewer is allowed if it does not interfere with disinfection or microbiological determination.
6 Maximum limit in more than one sample where less than 20 samples are examined per month.

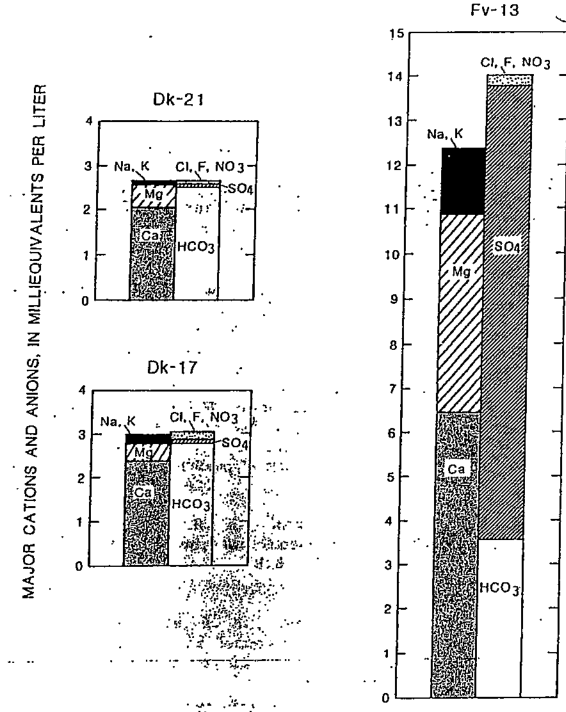


Figure 27.--Comparison of major cations and anions in wells Dk-21, Dk-17, and Fv-13.

SUMMARY AND CONCLUSIONS

Ground water in the Dickson area occurs primarily in the Warsaw Limestone. Secondary permeability, such as solution openings, are the principle avenues of ground-water movement. The underlying Fort Payne Formation is fine-grained and usually acts as the base of the aquifer. Test-well sites were chosen on the basis of topographic position, regolith thickness, and the lithology of the underlying formations. Data from the test wells were analyzed to relate geology and topography to ground-water occurrence. It appears that 1 regolith thickness and the 2 lithology of the bedrock are the main factors influencing the development of high-yielding solution openings.

Ten of the 26 test wells had thick regolith and a fine-grained limesto near the top of the coarse-grained bedrock. Seven of the 10 wells yielded 80 gal/min or more. The specific capacity for these seven wells ranged from 1.02 to 12.7 (gal/min)/ft of drawdown. High-yielding solution openings are more likely to develop in areas where there is thick regolith and a fine-grained limestone is present at the top of rock.

Aquifer tests were conducted at two wells which penetrated high-yielding solution openings. Well Dk-17 was pumped for 72 hours at an average rate of 155 gal/min with a specific capacity of 1.8 (gal/min)/ft. An 8-hour test was conducted at Dk-17 after additional casing was installed to seal off some upper zones. During this test, discharge was 120 gal/min with a specific capacity of 5.75 (gal/min)/ft.

A second well, Dk-21 was pumped at an average yield of 350 gal/min for 72 hours and had a specific capacity of 8.8 (gal/min)/ft. Further drilling at this site indicates that the solution opening may extend about 900 feet laterally. Most of the openings seemed to be very localized.

The Warsaw Limestone in the Dickson area is capable of yielding good quality water for drinking or industrial use. While low-yielding wells are the rule, the development of high-yielding wells is possible.

SELECTED REFERENCES

Burchett, C. R., 1977, Water resources of the upper Duck River basin, central Tennessee: Tennessee Division Water Resources, Water Resources Series No. 12, 103 p.

Burchett, C. R., and Hollyday, E. F., 1974, Tennessee's newest aquifer: Geological Society of America Abstract with Programs, v. 6, no. 4, p. 338.

Gold, R. L., 1980, Low flow measurements of Tennessee streams: Tennessee Division of Water Resources, Water Resources Series No. 14, 362 p.

Lohman, S. W., 1972, Ground-water hydraulics: U.S. Geological Survey Professional Paper 708, 70 p.

Marcher, M. V., 1962a, Stratigraphy and structure of rocks of Mississippian age in the northwestern Highland Rim, Tennessee: Journal of the Tennessee Academy of Science, v. 37, no. 4, p. 111-116.

______1962b, Petrography of Mississippian limestones and cherts from the northwestern Highland Rim, Tennessee: Journal of Sedimentary Petrology, v. 32, no. 4, p. 819-832.

Marcher, M. V., Bingham, R. H., and Lounsbury, R. E., 1964, Ground-water geology of the Dickson, Lawrenceburg, and Waverly areas in the western Highland Rim, Tennessee: U.S. Geological Survey Water-Supply Paper 1764, 50 p.

Moore, G. K., and Bingham, R. H., 1965, Availability of ground water in the western Highland Rim of Tennessee: Journal of the Tennessee Academy of Science, v. 40, no. 1, p. 22-26.

Moore, G. K., and Wilson, J. M., 1972, Water resources of the Center Hill Lake region, Tennessee: Tennessee Division of Water Resources, Water Resources Series No. 9, 77 p.

National Oceanic and Atmospheric Administration, 1979, Climatological Data annual summary Tennessee: National Oceanic and Atmospheric Administration, v. 80, no. 13, 10 p.

Parizek, R. R., and Drew, L. J., 1966, Random drilling for water in carbonate rocks: Pennsylvania State University, Water Resources Research Publication No. 3166, 22 p.

Piper, A. M., 1932, Ground water in north-central Tennessee: U.S. Geological Survey Water Supply Paper 640, 238 p.

Rima, D. R., and Goddard, P. L., 1979, Ground-water resources in the metropolitan region of Nashville, Tennessee: U.S. Army Corps of Engineers, Nashville District, Nashville, Tennessee, 44 p.

Tennessee Division of Water Quality Control, 1977, Public Water System in Rules of Tennessee Department of Public Health - Bureau of Environmental Health Services - Division of Water Quality control: Tennessee Department of Public Health, Bureau of Environmental Health Services, Division of Water Quality control, Chapter 1200-5-1, 29 p.

U.S. Environmental Protection Agency, 1976, National interim primary drinking water regulations: U.S. Environmental Protection Agency report EPA 570/9 - 76-003, 159 p.

_____1979, National secondary drinking water regulations: U.S. Environmental Protection Agency report EPA 570/9 - 76-000, 37 p.

White, W. A., 1960, Major folds by solution in the western Highland Rim of Tennessee [abs.]: Geological Society of America Bulletin, v. 71, no. 12, p. 2029.

Zurawski, Ann, 1968, Summary appraisals of the nation's ground-water resources - Tennessee region: U.S. Geological Survey Professional Paper 813-L, 35 p.

GROUND WATER IN THE DICKSON [illegible] TENNESSEE [illegible] WRI [illegible]

ATTACHMENT F

GROUNDWATER QUALITY ASSESSMENT PLAN
GRIGGS AND MALONEY

NOVEMBER 1994

(66 Pages)

DSWM
NEAC

GROUNDWATER QUALITY ASSESSMENT PLAN

DICKSON COUNTY LANDFILL
DICKSON COUNTY, TENNESSEE

NOVEMBER, 1994

Prepared By

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File Number 143-05

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GROUNDWATER QUALITY ASSESSMENT PLAN

DICKSON COUNTY LANDFILL
DICKSON COUNTY, TENNESSEE

1. INTRODUCTION

Griggs & Maloney, Inc. has been retained by Dickson County to prepare a site investigation plan to assess the groundwater quality at the Dickson County Landfill, Dickson, Tennessee. The Tennessee Division of Solid Waste Management (DSWM) directed Dickson County to develop a groundwater quality assessment plan after sampling from a spring near the landfill indicated solid waste constituents from the landfill may have migrated into the groundwater. This document describes the objectives of the investigation, provides background information concerning the landfill, and gives a detailed description of the work plan for the groundwater quality assessment.

2. SCOPE-OF-WORK

This Groundwater Quality Assessment Plan is designed to serve as the primary guidance document for the groundwater quality assessment at the landfill. The overall objectives of the assessment are, as required in the Solid Waste Regulations: determination of whether solid waste constituents have entered the groundwater and characterization of the concentrations and rate and extent of migration of waste constituents in the groundwater.

Multiple phases of investigation will be needed to complete the investigation. Because the need for an assessment monitoring program was initially indicated by sampling results from an off-site spring, the initial objective will be to determine whether the waste constituents detected in the spring came from the landfill. This will be accomplished by the installation of additional monitoring wells between the spring and the landfill. Additional hydrogeologic information will also be gathered by surveys to identity all springs, streams, and domestic and commercial water wells in the area. Other investigative work will be performed as necessary to meet the stated objectives of the investigation.

The Scope-of-Work for the assessment includes work to:

1) Install additional groundwater monitoring wells.
2) Develop and implement a groundwater sampling and analysis plan which will determine if solid waste constituents from the landfill have entered the groundwater.
3) Characterize the site's hydrogeology and determine the rate and extent of migration of waste constituents in the groundwater.
4) Identify all domestic and commercial water use within the area.
5) Prepare a comprehensive report of assessment findings and proposals for additional investigation or corrective action, if needed.

3. BACKGROUND INFORMATION

3.1. SITE LOCATION AND HISTORY

The Dickson County landfill is located on Eno Road approximately 1.5 miles southwest of Dickson, Tennessee. The entire landfill site, which includes areas previously used as a city dump and older landfilled areas, as well as the currently operating areas, includes approximately 85 to 95 acres. The current landfill operations are located on the western part of the site, and include a Class I balefill and a Class IV landfill. Figure 1 presents the location of the site on the U.S.G.S. 7.5 minute Dickson, Tennessee Quadrangle map.

The site was originally opened in the 1960's and operated as the city dump for the city of Dickson, until the site was sold to Dickson County in 1971. Part of the site was permitted as a sanitary landfill in 1980 and extension areas were permitted in 1988 and 1990. The latest set of engineering plans for the site were submitted in 1992 to meet the revised DSWM regulations. According to the plans, the Class I balefill operation will occupy approximately 14 acres and the Class IV landfill will occupy approximately 2.3 acres.

Four monitoring wells were installed to monitor the groundwater at the landfill. Two of the wells, all believed to be downgradient from portions of the landfill, have been regularly sampled to meet groundwater monitoring requirements. One of the wells, believed to be at an upgradient location, was dry from the time of installation, and has since been abandoned. As a background reference, Sullivan Spring, which is located about 0.3 miles north-northwest of the landfill, has been sampled to replace the dry well. Figure 2 shows the approximate locations of the monitoring wells and Sullivan Spring.

In March of 1994, the wells and spring were analyzed for the first time for the Appendix I parameters required by the revised DSWM regulations. The sampling results indicated levels of trichloroethylene (TCE) and cis-1,2-dichloroethylene were present in the sample obtained from Sullivan Spring. TCE was detected at 0.018 mg/L, which is above the maximum contaminant level (MCL) of 0.005 mg/L. In June, the two wells and Sullivan Spring were sampled again for the Appendix I parameters. In Sullivan Spring, TCE was detected at 0.083 mg/L, and 1,2-Dichloroethene was detected at 0.019 mg/L, which is above the MCL of 0.007 mg/L. Cis-1,2-Dichlorothene was also detected, but at levels below the MCL. In September, Sullivan Spring was resampled and again TCE and 1,2-Dichloroethene were detected above the MCL. Samples were also taken in Worley Furnace Branch, at locations upstream and downstream of the discharge point of Sullivan Spring. The contaminants were not detected in the upstream sample.

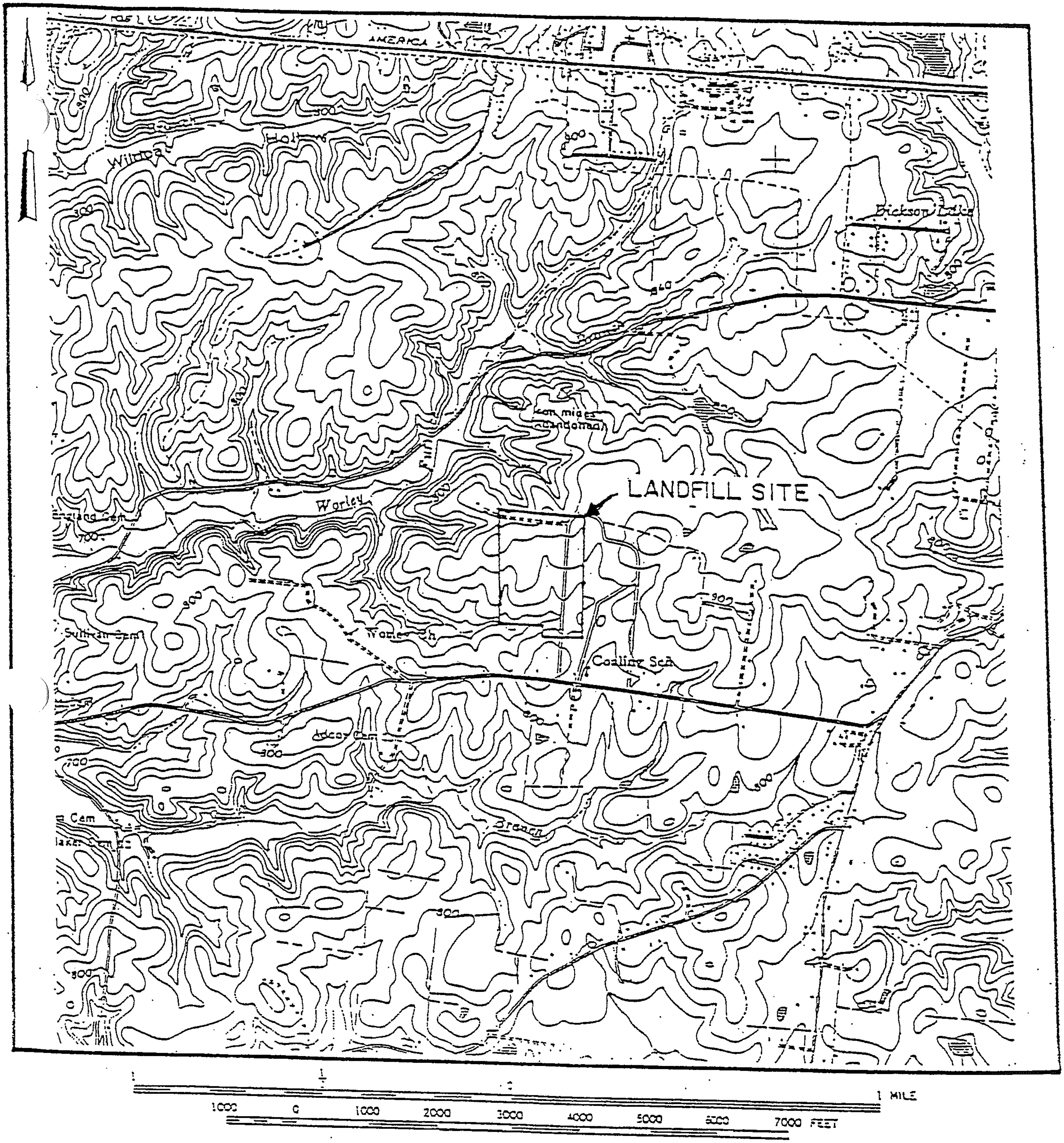

Figure 1
Site Location/Topographic Map

Groundwater Quality
Assessment Plan
Dickson County Landfill
Dickson County, Tennessee

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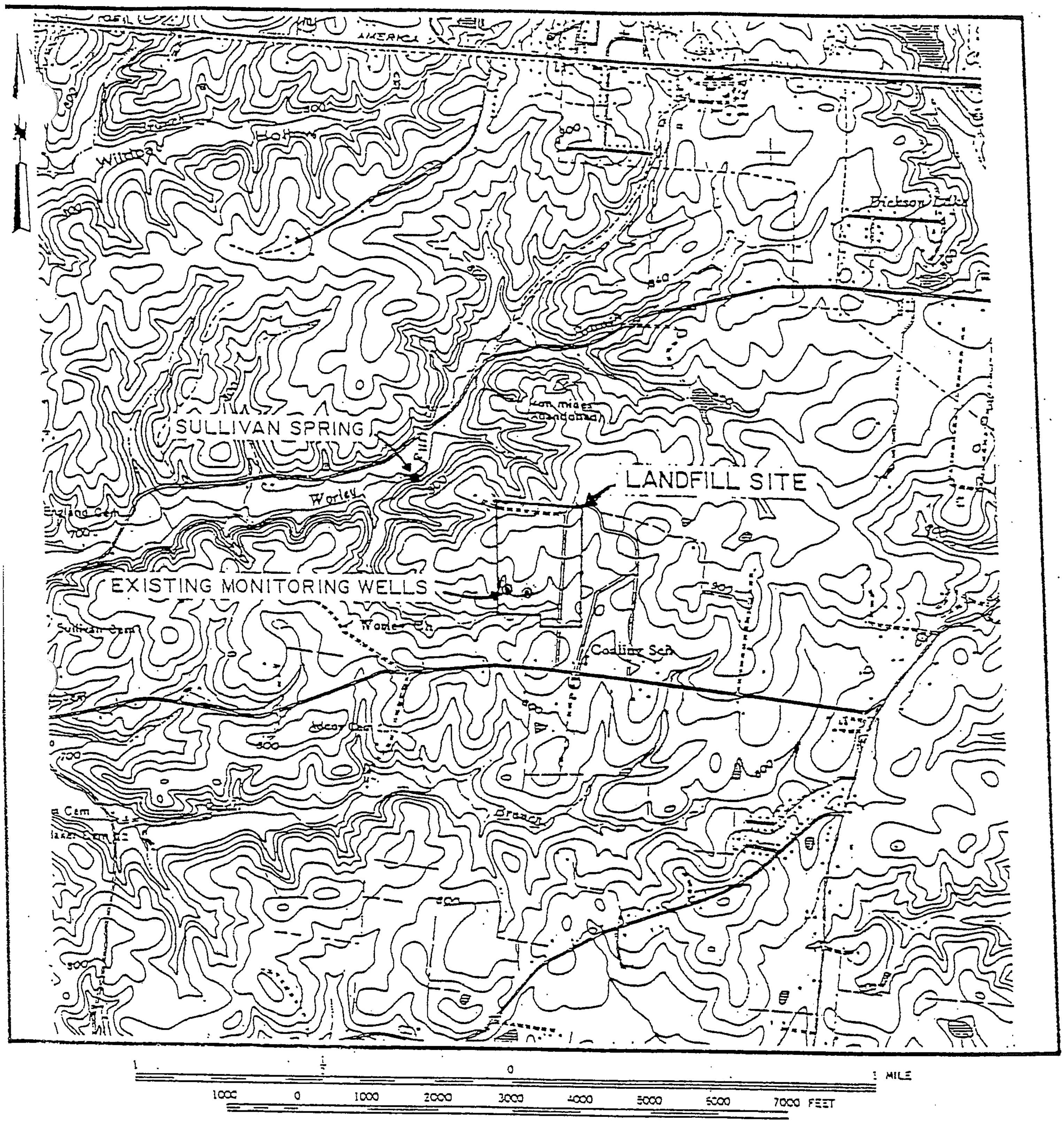


Figure 2
Site Location Map Showing Existing Monitoring Wells & Spring

Groundwater Quality
Assessment Plan
Dickson County Landfill
Dickson County, Tennessee

GRIGGS & MALONEY INCORPORATED
Engineering & Environmental Consulting

Sullivan Spring is used as a drinking water source by two families. At the time of the September sampling, the residences were notified by Mr. Jim Lunn, of Dickson County, that they should not use the water for drinking until further notice. The Division of Water Pollution Control was also notified of the findings at this time. In September, surface water sampling was conducted at various points on West Piney Creek. Sampling did not reveal detectable levels of any of the parameters. Residential wells on Furnace Hollow Road were also sampled during September. The laboratory results did not detect any of the parameters in question. (Gardner, 1994)

3.2. GEOLOGY

The Dickson County Landfill is located on the rolling plateau of the western Highland Rim, a section of the Interior Low Plateaus Physiographic province. The region is characterized by rolling terrain which has been cut by numerous streams. A mantle of unconsolidated regolith, of varying thickness, overlies Mississippian carbonate bedrock. (Bradley, 1984)

The landfill site is located on a rolling upland area which drains primarily toward Worley Furnace Branch and it's tributaries to the southwest, west, and northwest. Slopes are gentle to moderate within the landfill property boundaries, but are steep along the upland slopes. Relief over the landfill site is approximately 60 feet, with the highest elevations along the northern end of the landfill and the lowest elevations near the southwestern corner. Over 120 feet of relief exists between the highest areas of the landfill and Worley Furnace Branch.

The uppermost geologic formations in the area of the landfill are, in descending order: the St. Louis Limestone, the Warsaw Limestone, and the Fort Payne Formation, all of which are Mississippian in age. The regional dip of the formations is to the northwest. (Bradley, 1984)

Regolith variable 25-80 ft

The St. Louis Limestone caps the uplands over most of the area. At the landfill, for the most part, the unit has weathered to clay regolith. Borings at the landfill have identified the regolith as red, reddish-brown or orange, moderate to highly plastic, silty clay soils with varying amounts of chert fragments and blocks and nodules of chert. (ATEC, Geotechnical and Hydrogeologic Investigation, 1992) The borings have revealed that the unconsolidated soils are thick beneath the landfill site. The previous geotechnical borings and wells were drilled to depths ranging from 25 to 39 feet below the surface. Some of the auger borings were believed to have refused ~~on~~ dense chert beds and the ATEC report estimated limestone bedrock to be approximately 65 to 90 feet below the ground surface.

7

Bradley, 1984, estimated the regolith in the uplands of the Dickson area to generally range from 50 to more than 150 feet thick. Comparison of depths to bedrock for residential wells and test wells in the area near the landfill found the actual regolith thickness to be highly variable within short distances, which indicates that the bedrock surface is likely pinnacled. One test well drilled at the southeastern corner of the landfill was drilled to 331 feet before encountering bedrock. Where not weathered to regolith, the St. Louis Limestone is typically a yellowish-brown, fine-grained, cherty limestone. (Bradley, 1984)

The Warsaw Limestone underlies the St. Louis Limestone. Bradley, 1984, estimated the top of the Warsaw limestone to be near the 740 foot contour in the area of the landfill. This would place the top of the Warsaw at about 60 to 130 feet beneath the landfill site. The Warsaw Limestone is typically a thick-bedded, light-colored, medium- to coarse-grained, fossil fragmental limestone. Locally the upper part of the Warsaw may be weathered to clay regolith in some locations in the vicinity of the landfill. The unit is approximately 100 feet thick in the area. (Bradley, 1984)

The Fort Payne Formation is typically a calcareous, dolomitic, very cherty siltstone. It is estimated to have a maximum thickness of approximately 250 feet in the Dickson Area. (Bradley, 1984)

3.3. HYDROLOGY

3.3.1 SURFACE WATER

The landfill site drains primarily to the southwest, west, and northwest toward Worley Furnace Branch and it's tributaries. Worley Furnace Branch is located approximately 0.3 miles north-northwest of the landfill. The headwaters of a tributary of the stream begin at the southern end of the active landfill area. Portions of the southeastern part of the old city dump / landfill area drain to the south toward Baker Branch. Both Worley Furnace Branch and Baker Branch flow into West Piney River, which is located approximately 1.5 miles west of the landfill. All of the streams are within the Tennessee River Basin.

Numerous springs are located in the Dickson area. The spring believed to be the closest to the landfill is Sullivan Spring, which discharges into Worley Furnace Branch about 0.3 miles north-northwest of the landfill. The altitude of the spring is near the 720 foot elevation. The spring appears to issue from the limestone bedrock which outcrops along the valley wall of Worley Furnace Branch.

3.3.2 GROUNDWATER

According to Bradley, the groundwater system in the Dickson area is primarily recharged from precipitation in the uplands where the regolith is thick. Recharge enters the regolith, which stores the water and transmits it slowly downward to points where it can enter the bedrock system or flow along the bedrock-residuum contact. Although the regolith stores large quantities of water, due to the low permeability of the clay, the regolith will in most cases yield little water.

The primary aquifer in the Dickson area occurs in the solutionaly enlarged bedding plane openings in soluable limestone. The great majority of wells in the area are screened in the Warsaw limestone and, with one exception, all springs recharge from the Warsaw. (Bradley, 1984) The dense cherty Fort Payne Formation is generally an underlying confining layer, but does yield water in some wells.

A regional water level contour map taken from Bradley, 1984, is shown in Figure 3. The contour map shows water levels in the Dickson area based upon measurements in wells and springs in 1960. As the map shows, groundwater flow patterns are similar to surface flow patterns, as groundwater generally flows from the uplands toward the valleys. In the valleys, groundwater is discharged at springs or seeps. Based upon the map, on a regional scale groundwater in the area of the landfill is moving in a west-southwesterly direction.

Flow in regolith?

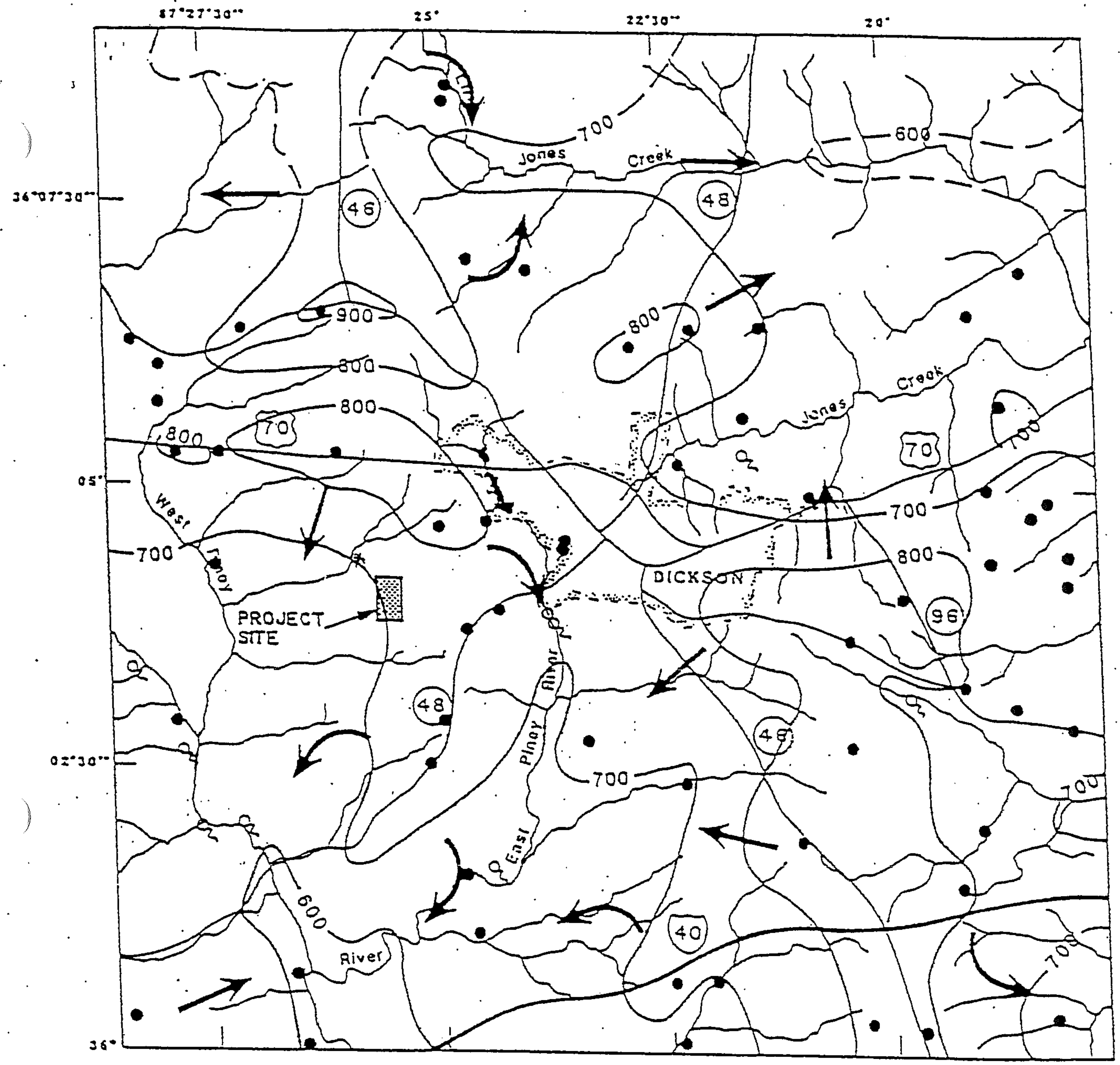
The existing monitoring wells at the landfill are screened immediately above the bedrock surface. (ATEC geotechnical report) The nature of flow within the regolith is uncertain. The wells show widely varying water levels and two of the four wells have been dry at times. The direction of groundwater flow cannot be determined based upon the information from the existing wells. Groundwater flow within the regolith may be discontinuous across the site, and controlled by the presence of pinnacles, regolith thickness and/or variable rates of recharge to solution openings in bedrock.

Good

Based upon the thickness of regolith, the primary aquifer beneath the landfill should occur in solution enlarged openings in the Warsaw limestone. Of the 20 wells known to be located within a one-mile radius of the site, all but 4 of the wells are deeper than 125 feet, and most are believed to be drilled more than 50 feet into bedrock. (ATEC, geotechnical report) In drilling test wells into the Warsaw limestone in the Dickson area, Bradley found solution openings which ranged from less than 1 foot to more than 40 feet thick. In general the smaller openings were clean, water bearing zones, while the larger openings were partially or completely filled with clay. Solution openings which occurred below fine-grained "cap rock" near the top of bedrock were more likely to yield large amounts of water. The size and number of the solution openings decreased with depth. (Bradley, 1984)

Assuming recharge = local recharge + regional recharge could move to deeper openings and then up

Sullivan Spring appears to be recharged from the Warsaw limestone, which outcrops along the valley wall of Worley Furnace Branch. It is expected that the bedrock solution openings which recharge Sullivan Spring would most likely be at altitudes above or equal to the altitude at Sullivan Spring.



Base from U.S. Geological Survey, 1:24,000 quadrangles: Burns (1953), Charlotte (1958), Dickson (1953), and Vanleer (1958)

4000 0 4000 8000 FEET

1000 0 1000 2000 METERS

Hydrology modified from Marcher, Bingham, and Lounsbury (1964)

EXPLANATION

— 600 — — POTENTIOMETRIC CONTOUR — Shows altitude of water table, March 1960. Dashed where approximately located. Contour interval 100 feet. National Geodetic Vertical Datum of 1929

Wells with water levels measured March, 1960

Springs

Direction of ground-water flow

NOTE: Map taken from Bradley.

Figure 3
Regional Water Level Contour Map

Groundwater Quality
Assessment Plan
Dickson County Landfill
Dickson County, Tennessee

3.3.3 WATER USAGE

Figure 4 is a map adapted from the ATEC geotechnical investigation showing water well locations within a one-mile radius of the landfill. According to the ATEC report, the city of Dickson has 11 public wells east of the landfill site. According to Mr. Jim Lunn, with Dickson County, one additional city well is located next to the city water tank and the additional well is shown on the map. The city receives its water from Dickson City Lake, northeast of the site, and only two of the wells, 1398 and 1385, are actively used to ensure that the pumps are operational. Table 1 provides information concerning the water wells. (ATEC)

1389??

4. INVESTIGATION PROCEDURES

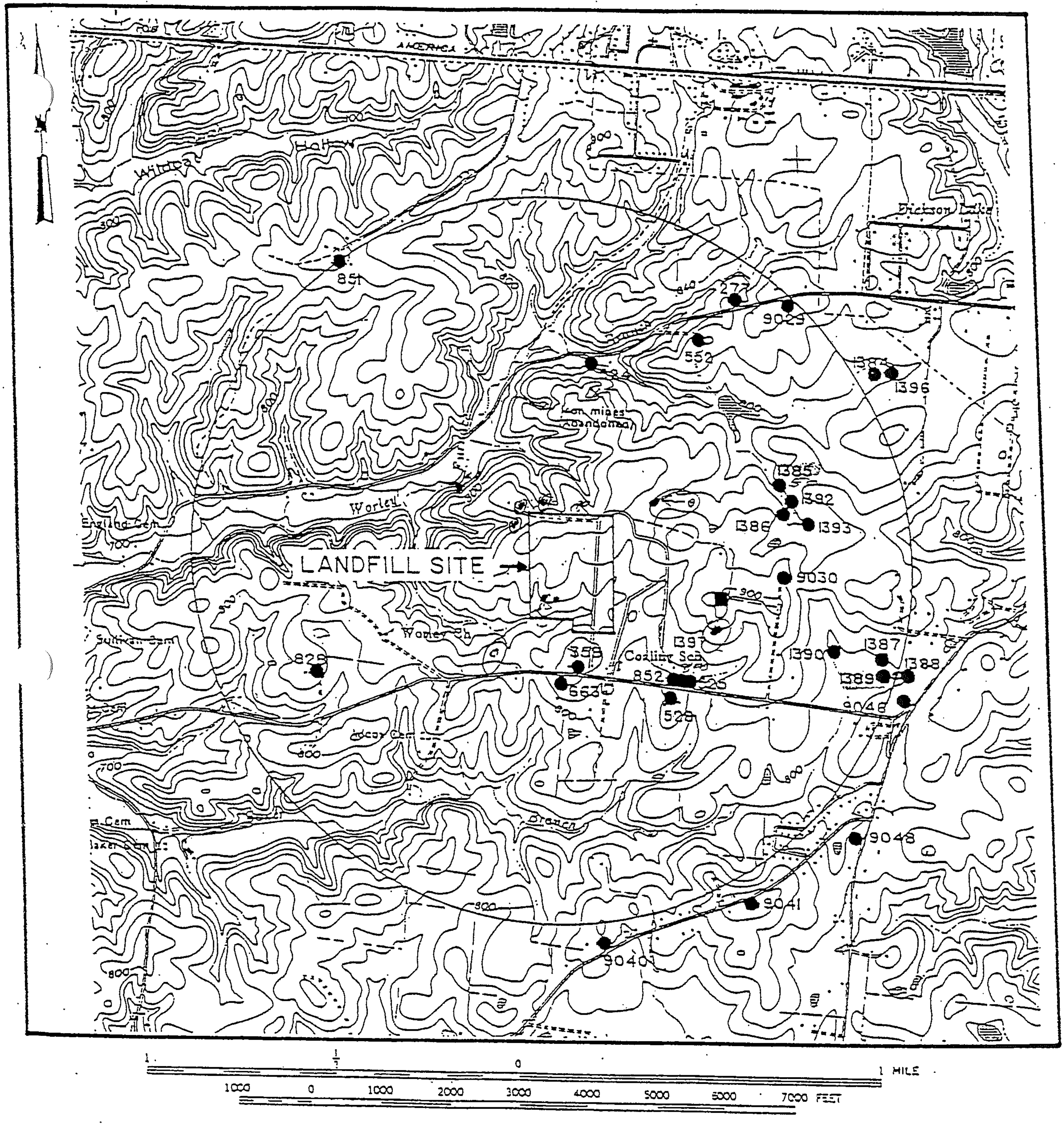
In order to meet the objectives which have been previously defined, the investigation will be performed in sequential phases. The initial phase will consist of the installation and sampling of monitoring wells, with the intended purpose of determining if, in fact, the contamination detected in Sullivan Spring came from the landfill. Based upon the results of the initial phase of work, subsequent phases will likely need to be performed to delineate the full extent of contamination at the site and to better define the hydrogeology of the landfill area.

4.1 MONITORING WELL LOCATIONS AND DEPTHS

In order to determine if the contamination detected in the spring came from the landfill, to begin the investigation a minimum of three additional monitoring wells will be installed. The wells will be located near the northwest corner of the landfill, between the landfill and Sullivan Spring. The proposed well locations are shown in Figure 5.

The depths at which the wells will be installed are dependent upon the depths at which groundwater is encountered and upon the results of preliminary sample screening which will be performed as the borings are advanced. If groundwater is encountered above the soil/ bedrock interface, groundwater samples will be obtained through use of either a HydroPunch sampler or from the installation of temporary wells. The samples will be analyzed for the list of parameters which have previously been detected in Sullivan Spring. ✓ If contamination is detected, permanent wells will be completed above the soil/bedrock interface. If contamination is not detected in the preliminary sampling, the soil aquifer will be cased off, and the boring will be advanced into bedrock. Any zone of groundwater encountered as the boring is advanced through bedrock, will be sampled to see if the indicator screening parameters are detected. If conditions warrant, multiple strings of casings will be used to seal off multiple aquifers.

field?? CL??



LEGEND

● – Well location and number adapted from ATEC Report.

■ – Addition Well location supplied by Mr. Jim Lunn of Dickson County.

Figure 4
Water Well Location Map

Groundwater Quality
Assessment Plan
Dickson County Landfill
Dickson County, Tennessee

TABLE NO. 1
DICKSON COUNTY SANITARY LANDFILL
WATER WELL INFORMATION

WELL NO.	OWNER	DATE COMPLETED	TOTAL DEPTH	TOTAL YIELD	BOTTOM CASING	WATER BEARING ZONE	USE
277	C. Bradford	4/18/67	100	5	87	85	Home
358	J. Puckett	7/12/68	160	3	79	220	Home
521	J. Holt	3/25/64	129	4	128	125	Home
525	R. Holt	7/16/70	300	2	98	260	Home
528	A. Harris	8/31/70	360		71	120	Home
552	G. Donegan	2/24/70	105	50	100	100	Home
663	R. Buchanan	7/30/71	130	10	127	130	
828	E. Lovelace	4/28/73	200	2	47		Home
851	J. Horner	6/18/73	160	5			Home
852	H. Holt	6/25/73	340		160		Home
1384	City of Dickson	12/1/80	300	4	136	220	Municipal
1385	City of Dickson	10/20/80	160	400	106	143	Municipal
1386	City of Dickson	10/6/80	250	20	106	116	Municipal
1387	City of Dickson	10/4/80	300	8	103	252	Municipal
1388	City of Dickson	10/2/80	250	150	181	197	Municipal
1389	City of Dickson	8/4/80	300	150	144	180	Municipal
1390	City of Dickson	7/24/80	350	14	115	307	Municipal
1392	City of Dickson	7/14/81	280	165	127	145	Municipal
1393	City of Dickson		320	12	162	245	Municipal
1396	City of Dickson	7/7/80	280	110	127	130	Municipal
1397	City of Dickson	7/2/80	340	175	318	330	Municipal
9029	K. Walker		75		75		Home
9030	J. Robinson		212		107		Home
9040	D. Sanders		110		100		Home
9041	D. Sanders		133				Home
9046	D. Donegan		125				Home
9048	W. R Street		155		155		Home

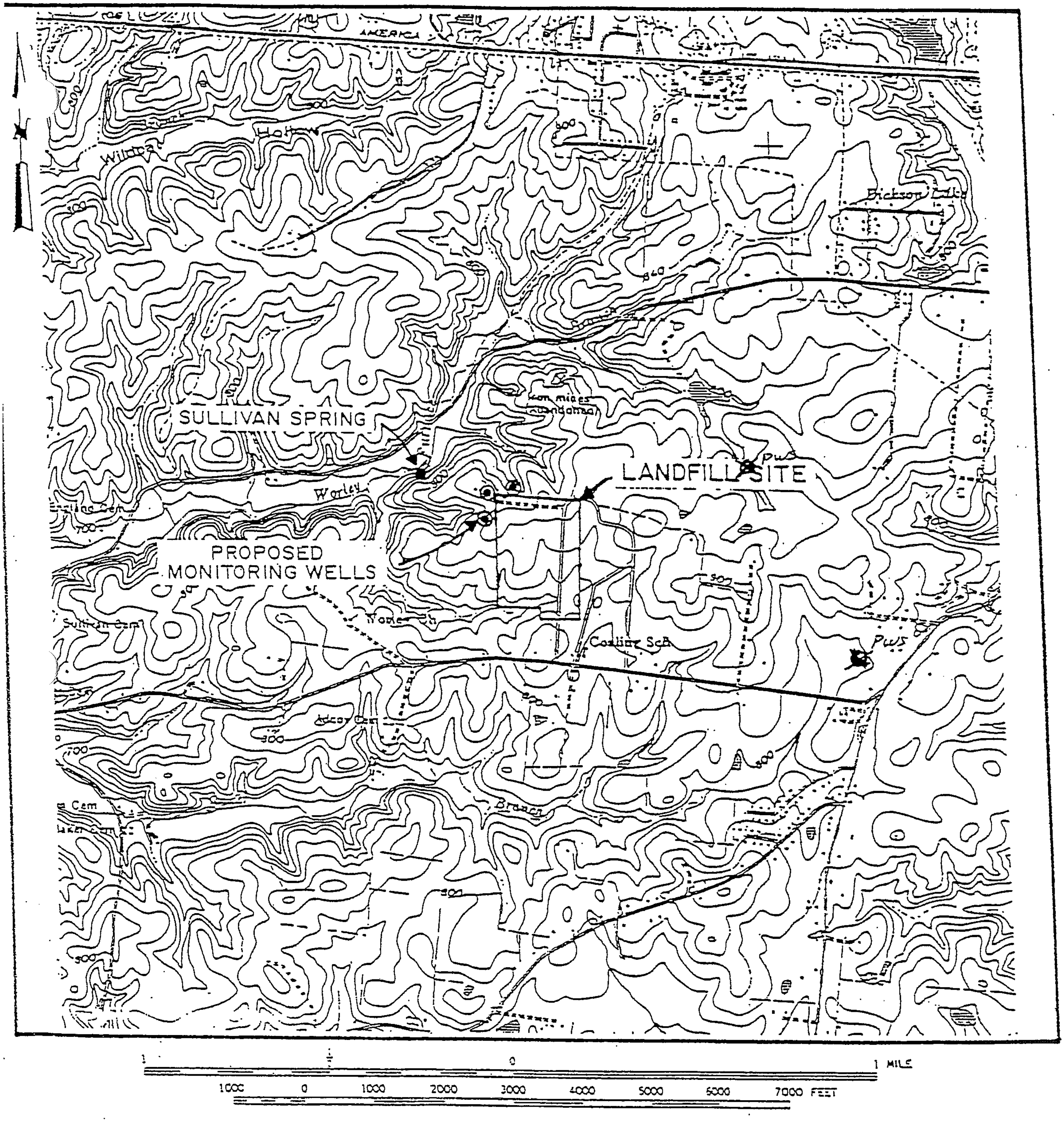


Figure 5
Proposed Monitoring Well Location Map

Groundwater Quality
Assessment Plan
Dickson County Landfill
Dickson County, Tennessee

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At each location, the monitoring well will be installed in the zone of groundwater which indicates contamination, or if contamination is not indicated, in the zone of bedrock aquifer which indicates the highest yield. If contamination is detected at any of the wells, it is expected that additional wells will be necessary.

4.2 WELL DRILLING METHODS

From the ground surface, until refusal is encountered upon rock, drilling will be performed using hollow stem auger methods. Borings will be advanced using 4-1/4" ID hollow-stem augers. In order to characterize the soil conditions encountered, split spoon samples will be taken using a 2-foot long, 2-inch OD, 1.375 inch ID split spoon sampler. Split spoon samples will be taken at intervals of at least every ten (10) feet. All soil samples will be monitored with an HNu-101 Photoionization detector (PID), and if positive readings occur, selected samples may be sent to a laboratory for analysis.

Drilling into bedrock will be performed using air rotary drilling techniques. In order to seal off the soil aquifer, a minimum 14" diameter borehole will be advanced at least 2 feet into competent bedrock and a 10" diameter steel casing grouted into place. A 5-5/8" bit will be used to advance the boring into bedrock. Should conditions require the isolation of multiple bedrock aquifers, a 10" diameter borehole will be advanced and a 6" steel casing set to isolate the aquifers.

All soil and rock cuttings from the drilling operation will be placed on plastic beside the borehole and if contamination is indicated will be disposed of in accordance with DSWM regulations.

All soil and rock samples will be visually examined by an on-site geologist, classified, and the information entered on subsurface exploration borehole logs.

4.3. DECONTAMINATION PROCEDURES

Strict decontamination procedures will be followed throughout the investigation. The minimum requirements for decontamination of drilling equipment are as listed below.

All drilling equipment must be cleaned and decontaminated prior to and after each use on the site. A high pressure steam cleaner will be utilized to remove all foreign substances, dirt, oil and grease, rust, etc. from all trucks, augers, rods, drill stems, bits, casings, tremie pipe, and hoses used at the site. Decontamination will be performed on a decontamination pad, constructed so as to contain all wash waters, debris and residue from the augers and overspray occurring during the pressure washing operation. The pad will be constructed so as to enable the collection and transfer of waste into drums or other containers for storage and proper disposal.

To clean the drilling equipment the following procedure will be used:

1. Wash with hot water from a high pressure steam washer.
2. Rinse thoroughly with hot tap water or steam, if available.
3. All wash and rinse water used in the decontamination process will be collected for proper disposal according to current rules and regulations.
4. After each cleaning event, the equipment will be allowed to air dry, and then checked with the HNu PID for evidence of volatile organics, and visually for cleanliness.

4.4. WELL CONSTRUCTION METHODS

4.4.1 SINGLE CASED WELL INSTALLATION PROCEDURES

4-in

The casing and screen will be constructed of two (2) inch I.D., pre-cleaned, flush threaded, Schedule 40 PVC. The screen will be ten (10) feet in length and will have 0.01 inch factory milled slots. The well screen will be terminated with a threaded end cap and the casing will be terminated with a locking, watertight cap. Should preliminary sample screening results indicate high levels of contamination, four (4) inch diameter wells may be installed for potential use as recovery wells.

The annular space between the well screen and the borehole wall will be filled with a filter pack to a depth of approximately two (2) feet (minimum) above the top of the screened section. A weighted tape will be used to help prevent bridging and ensure the proper placement of the filter pack. The filter pack will consist of clean, washed, well sorted silica sand.

A filter pack seal of at least two (2) feet of bentonite pellets will be placed immediately above the sand. A weighted tape will be used to help prevent bridging and ensure the proper placement of the filter pack seal. If the bentonite seal is placed above the water table, two gallons of potable water will be used to hydrate the pellets. A minimum of 1 hour will be allowed for the pellets to hydrate.

The remaining annular space, from the top of the filter pack seal to within two feet of the surface, will be filled with a bentonite/cement grout. The grout will consist of a mixture of Portland cement and 4-6% powered bentonite mixed to a density of 13.5 to 14.1 lbs/gallon. A tremie pipe will be used to place the annular grout.

The final two feet of the annular space will be filled with concrete and a locking above ground steel protective cover will be set into place. The concrete apron around each well will be sloped so that surface drainage will be diverted. Each monitoring well will be clearly marked as a monitoring well and numbered. Figure 6 presents a diagram of a single cased monitoring well proposed for use at the site.

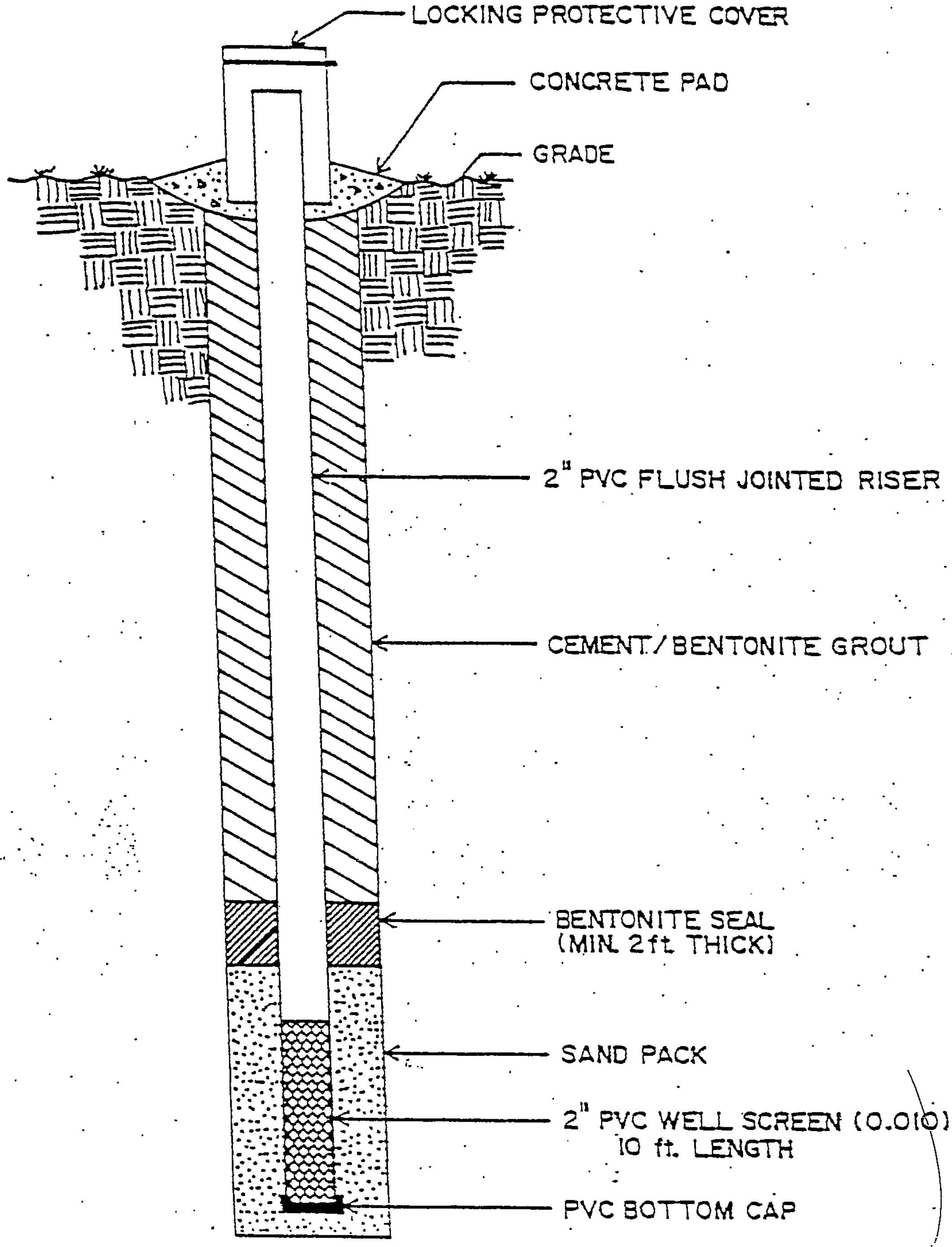

Figure 6
Single Cased Monitoring Well Construction Diagram

Groundwater Quality
Assessment Plan
Dickson County Landfill
Dickson County, Tennessee

Project 143-05 November, 1994

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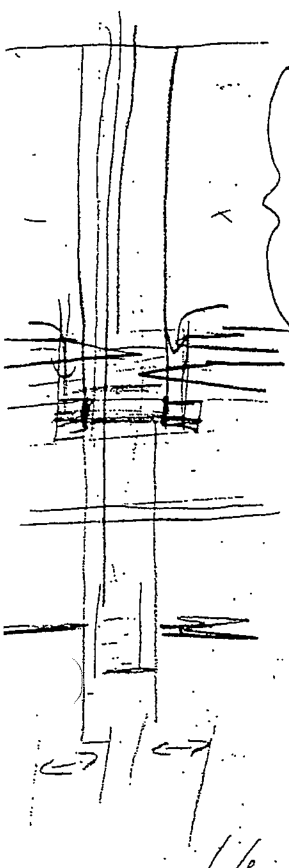
4.4.2 DOUBLE CASED WELL INSTALLATION PROCEDURES

To prevent the vertical movement of contaminants within a borehole or to prevent the cross contamination of multiple aquifers, double cased monitoring wells will be installed when monitoring a separate, deeper aquifer for contamination.



In casing off the soil aquifer, a minimum fourteen (14) inch diameter borehole will be advanced at least two (2) feet into competent bedrock. A ten (10) inch diameter precleaned black steel outer casing will be used. Where multiple strings of outer casings are used, the outer borehole diameter will be a minimum of four (4) inches larger than the outside diameter of the casing. The annular space between the inner casing and the outer casing will also be a total of four (4) inches

The outer casing will be grouted into place using a bentonite/cement grout. The grout will consist of a mixture of Portland cement and 4-6% powered bentonite mixed to a density of 13.5 to 14.1 lbs/gallon. A tremie pipe will be used to place the annular grout. The grout will be allowed to set for a minimum of 24 hours before continuation of drilling activities.

The inner casing and screen will be constructed of two (2) inch I.D., pre-cleaned, flush threaded, Schedule 40 PVC. The screen will be ten (10) feet in length and will have 0.01 inch factory milled slots. The well screen will be terminated with a threaded end cap and the casing will be terminated with a locking, watertight cap.

The annular space between the well screen and borehole wall will be filled with a filter pack to a depth of approximately two (2) feet (minimum) above the top of the screened section. A weighted tape will be used to help prevent bridging and ensure the proper placement of the filter pack. The filter pack will consist of clean, washed, well sorted silica sand.

A filter pack seal of at least two (2) feet of bentonite pellets will be placed immediately above the sand. A weighted tape will be used to help prevent bridging and ensure the proper placement of the filter pack seal. If the bentonite seal is placed above the water table, two gallons of potable water will be used to hydrate the pellets. A minimum of 1 hour will be allowed for the pellets to hydrate.

The remaining annular space, from the top of the filter pack seal to within two feet of the surface, will be filled with a bentonite/cement grout. The grout will consist of a mixture of Portland cement and 4-6% powered bentonite mixed to a density of 13.5 to 14.1 lbs/gallon. A tremie pipe will be used to place the annular grout.

The final two feet of the annular space will be filled with concrete and a locking above ground steel protective cover will be set into place. The concrete apron around each well will be sloped so that surface drainage will be diverted. Each monitoring well will be clearly marked as a monitoring well and numbered. Figure 7 presents a diagram of a double cased monitoring well proposed for use at the site.

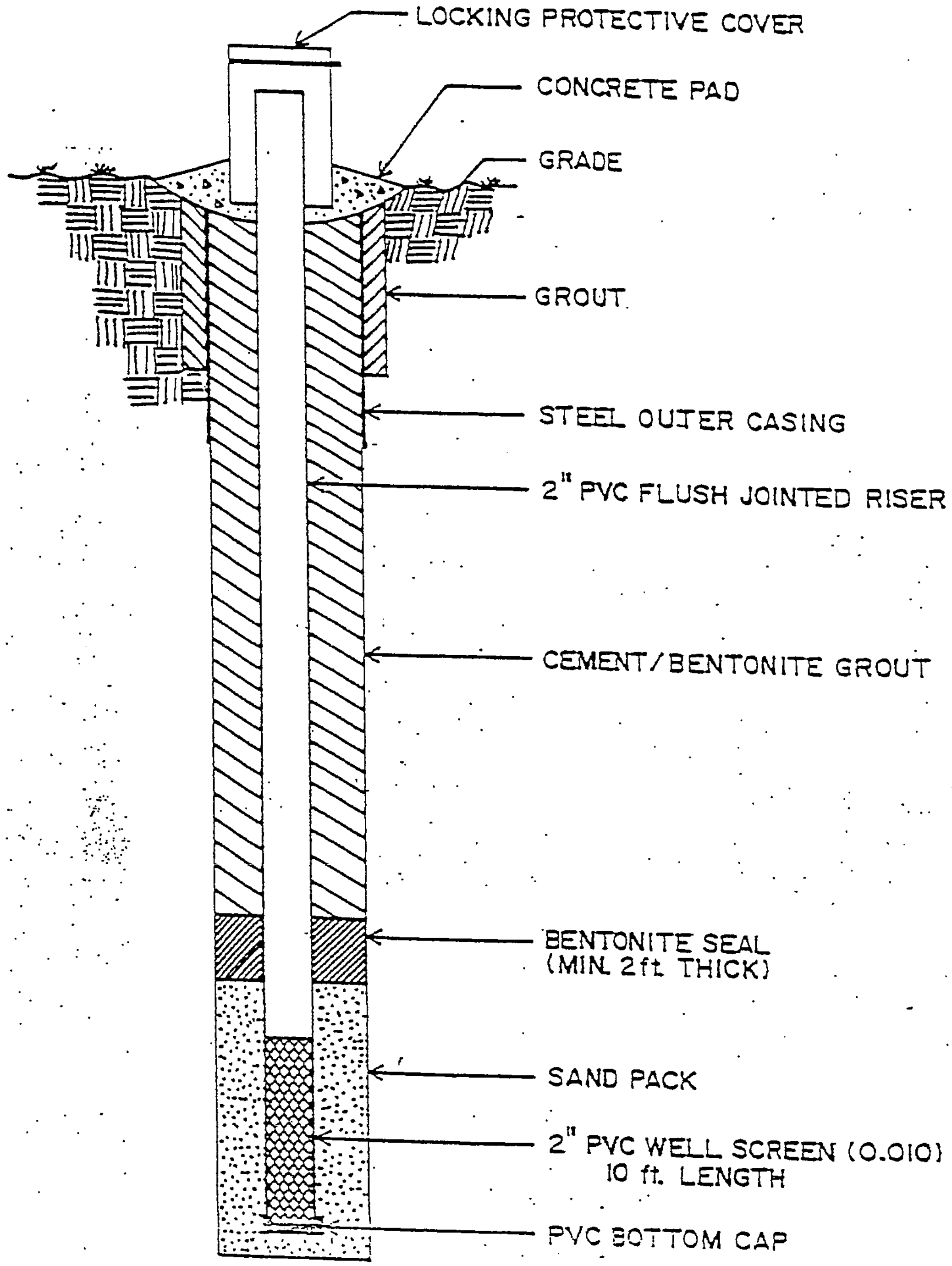


Figure 7
Double Cased Monitoring Well
Construction Diagram

Groundwater Quality
Assessment Plan
Dickson County Landfill
Dickson County, Tennessee

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Project 143-05 November, 1994

GRIGGS & MALONEY, INC.

MONITORING WELL DEVELOPMENT FORM

PROJECT NO.:		PROJECT NAME:			
WELL ID NO.:		ELEVATION (ft):		WELL DIAMETER:	

PERSONNEL:			
INSTALLED DATE:		DEVELOPMENT DATE:	
DEVELOPMENT METHOD:			

SAFETY PROCEDURES:	RESPIRATORY:		GLOVES:	
	CLOTHING:			

TOTAL WELL DEPTH (ft):		DEPTH TO WATER:	
DEPTH OF WATER COL., ft.:			

VOL. OF PURGE WATER (gal): FACTOR x WATER COL., ft.=	
3 x CALCULATED PURGE VOL.:	

WELL RECHARGE RATE:	FAST (<2hr.)		SLOW (>4 hr)	
	MED. (2-4hr)			

FREE PRODUCT:	YES:		NO:		QUANTITY:		DETECTION METHOD:	

WATER QUALITY INDICATORS

SAMPLE NUMBER	TIME	VOLUME PURGED GAL.	TEMP. °C	SPECIFIC COND. µMHOS	PH	CLARITY/ SEDIMENT
Initial		0				
After 1 Well Volume						
After 2 Well Volume						
After 3 Well Volume						
After 4 Well Volume						
After 5 Well Volume						
After 6 Well Volume						

Figure 8
Monitoring Well Development Form

Groundwater Quality
Assessment Plan
Dickson County Landfill
Dickson County, Tennessee

4.7. GROUNDWATER SAMPLING

Groundwater sampling includes the measurement of free phase product, static water level measurements, calculation of standing water volume, evacuation of the well, collection of the sample, and decontamination of the sampling equipment. The *"Sampling and Analysis Quality Assurance / Quality Control Plan"* included in Appendix B presents the details of the sampling and analysis process and will be adhered to during the performance of all groundwater sampling and analysis.

After developing the newly installed monitoring wells, the wells will be allowed to stabilize for a period of at least seven (7) days. Groundwater static water level elevations will then be measured. All water level measurements will be referenced from an established and documented point on the top of the well casing. The measurements will be correlated with mean sea level datum and measured to the nearest 0.01 foot.

After the water level measurements are performed in all wells at the site, each well will be purged and groundwater samples collected for submittal to the laboratory for analysis. Monitoring well purging and sampling forms will be completed for each purging and sampling event for each well.

Samples will be collected for analysis in the order of volatilization as follows:

1. Volatile Organics
2. Extractable Organics
3. Pesticides and Herbicides
4. Dibenzofurans/dibenzo-p-dioxins
5. Mercury
6. Metals
7. Cyanide
8. Sulfide
9. pH and Conductivity

Initially during well drilling activities, preliminary groundwater sampling will be performed using either HydroPunch sampling methods, temporary well installations, or sampling from the open bedrock borehole. The preliminary sampling will be used to determine the proper depth to screen the wells. Representative samples will be obtained and submitted to a laboratory for rush (24 hour) analysis.

4.8 GROUNDWATER ANALYSIS

All groundwater samples will be submitted to a certified laboratory, approved by the State of Tennessee, to perform the analytical procedures required by this plan. Groundwater samples will be analyzed per the latest edition of *USEPA, SW-846, "Test Methods For Evaluating Solid Waste, Physical/Chemical Methods."* Table 2 presents a detailed summary of the groundwater sample handling, preservation, and analysis requirements.

TABLE 2
GROUNDWATER SAMPLE HANDLING AND ANALYSIS SUMMARY
DICKSON COUNTY LANDFILL

846 not 8240
45 VOCs - 325
846 725
8270
846 pest 8080 200
8150 180
1000
35
40
25

ANALYSIS REQUIRED	CONTAINER	PRESERVATIVE	HOLDING TIME	ANALYTICAL METHODS	REFERENCE
VOC	3 x 40ml VOA	(4)	14 days	8010/8020/ 8260	SW-846
Extractable Organics	3 x 1Liter Amber Glass	None	7 days to extraction , 30 days after	8270	SW-846
Pesticides and Herbicides	3 x 1Liter Amber Glass	(6)	7 days to extraction , 30 days after	8150/8080	SW-846
Dibenzo- furans/Di-benzo-p-dioxins	3 x 1Liter Amber Glass	(6)	7 days to extraction , 30 days after	8280	SW-846
Mercury	Plastic 200 ml	(6)	28 Days	7470	SW-846
Cyanide	Plastic 300 ml	(3)	14 Days	9010	SW-846
Sulfide	Glass 100 ml	(7)	7 Days	9030	SW-846
Total Metals	Plastic 3X 1 Liter	(6)	6 months	6010	SW-846

1 40 ml glass VOA vial with Teflon lined septa and hole cap.

2 Cool to 4 ° C

3 NaOH >12.0, Cool to 4 ° C.

4 Cool to 4° C., HCL pH <2.

5 Liter glass or plastic bottle.

6 Nitric acid to pH less than or equal to 2.0.

7 ZN Acetate (4 drops 2N./100mls.+NaOH >9.0)

4.9 SAMPLE LABELING AND HANDLING

All samples will be handled as prescribed by methodology set forth in the latest edition of *USEPA, SW-846, Test Methods For Evaluating Solid Waste, Physical/Chemical Methods.*

The sample label will contain the following information:

- Project location and project number
- Sample location, borehole or monitoring well number, or depth
- Method of collection
- Date and time of collection
- Samplers identifying name or initials
- Sample type
- Analysis requested
- Method of preservation

An example of a sample label is included in Appendix B. In addition to sample labels, sample seals may also be used to assure the integrity of the samples. A typical sample seal is also shown in Appendix B.

4.9.1 SAMPLE PACKAGING AND SHIPPING

Samples will be packaged to insure physical as well as chemical integrity. Samples will be delivered to the laboratory as soon as possible after sampling, preferably on the same day. If samples must be shipped by common carrier, use of next day service is required.

Prior to transport or shipping, the cooler will be packed with shock absorbent material to prevent breakage of the sample containers and prevent the coolant from shifting. Appropriate Chain-of-Custody documentation will be enclosed in the cooler with the samples. and the lid will be secured and sealed. The exterior of the cooler will be labeled with the name and address of the shipper and the address to be shipped to, and the total weight of the package. Warning labels will be affixed noting "THIS SIDE UP" and "FRAGILE" and any appropriate hazardous warning.

4.9.2. SAMPLE CHAIN-OF-CUSTODY

Because the samples collected from the investigation may be involved in legalistic proceedings at a later time, Chain-of-Custody documentation of all samples must be maintained. A Chain-of-Custody is required anytime the sample leaves the custody of the sampler. The possession of samples from the time of collection must be traceable.

A typical Chain-of-Custody form is included in Appendix B. The form must be filled out completely, legibly, and accurately and accompany the sample at all times for documentation of the sample handling. When common carriers or shippers are utilized to ship samples to the laboratory, the receipts and shipping manifest must be attached to the Chain-of-Custody to complete the chain. When samples are split between two or more parties, a separate Chain-of Custody shall be prepared and accompany each sample.

4.10 SAMPLING QUALITY ASSURANCE / QUALITY CONTROL

Trip blanks, equipment blanks, field blanks, split samples, and duplicate samples are examples of quality assurance/quality control (QA/QC) sampling requirements. QA/QC samples are handled, packaged, shipped, and analyzed in the same manner as the regular soil and groundwater samples. QA/QC samples are introduced into the total measurement system as a means of control and evaluation of the level of contamination and variability of results as contributed by potential artifacts and interferences arising at any point in the measurement process.

QA/QC samples are designed to measure:

1. The integrity of the sample container and sample equipment cleaning process;
2. The actual process of sample collection;
3. The purity of the sample preservatives and additive reagents and chemicals;
4. The influence of the site's environmental conditions on the samples;
5. Cross contamination of samples due to improperly cleaned sampling equipment; and
6. Indeterminate artifacts introduced during sample transport from containers, preservatives, cleaning agents, and sampling equipment.

Table 3 summarizes the number and frequency of the QA/QC sample collection.

4.10.3 DUPLICATE SAMPLES/SPLIT SAMPLES

Duplicate samples are utilized to monitor the ability of the sampling procedures to produce reproducible results and to provide the laboratory with sufficient sample to perform laboratory matrix spike and duplicate sample analysis. Duplicate samples are essentially identical samples. They are collected, preserved, handled, shipped, stored, and analyzed in the same manner as the regular samples.

One duplicate sample will be collected for each sample set of ten (10) samples collected for submittal to the laboratory.

Split samples are duplicate samples split between two or more parties for separate analysis by unrelated laboratories.

4.10.4 FIELD BLANKS

Field blanks are utilized to evaluate the sample container filling procedure, the effects of environmental contaminants at the site, purity of preservatives or additives.

Field blanks are prepared in the field, on-site, by filling appropriate sample containers with DI water and adding appropriate preservatives and additives as required. The field blank sample is then grouped, handled, stored, and transported with the true samples collected at the site.

Field blanks will be collected at the rate of one (1) sample for each twenty (20) samples collected.

4.11 SURVEY FOR STREAMS, SPRINGS, AND WELLS

In order to identify possible discharge points of groundwater from beneath the landfill, the investigation will include a survey to identify all streams and springs in the area. The survey will include the identification of all domestic and/or commercial water uses within at least a one-mile radius of the site. Further testing of samples from the offsite streams, springs, or wells may be recommended.

4.12 ADDITIONAL PHASES OF THE INVESTIGATION

Upon conclusion of the initial phase of monitoring well installations, sampling, and survey for springs, streams, and wells in the area, it is expected subsequent phases of investigation will likely need to be performed to delineate the full extent of contamination at the site, and to better characterize the area hydrogeology.

The subsequent phases of investigation may include such activities as additional well installations, slug and/or pump testing of wells, sampling of other springs, streams, or wells in the area, and injections of dye to characterize flow directions.

Since the exact nature of the need for subsequent investigation cannot be known until additional work is completed, the scope of work for each additional phase of investigation will be submitted as an Addendum to the Work Plan prior to performance of the work.

5.0 REPORT OF FINDINGS

Upon completion of the monitoring well installation and sampling, and receipt of all laboratory testing results, a report will be prepared which includes the following:

1) Documentation of all monitoring well drilling, installation, and sampling activities.
2) Laboratory analytical reports of the groundwater sampling results.
3) Characterization of the groundwater potentiometric surface elevations and flow directions.
4) Results of the well, spring, and stream survey.
5) Results of any additional hydrogeologic testing.
6) Recommendations for additional phases of investigation, if necessary.

6.0 SCHEDULE OF IMPLEMENTATION

The following schedule is presented as an example of the expected completion times for the scope-of-work to be performed.

DAYS FOR COMPLETION	ACTIVITIES OR TASKS TO COMPLETE
Day 0	Approval of Groundwater Quality Assessment Plan
Day 10	Notification of DSWM of schedule for well installation
Day 30	Begin monitoring well drilling and installations
Day 45	Completion of sampling event # 1- All Appendix II parameters
Day 60	Completion of sampling event # 2- Append. II detected + Appendix I
Day 75	Completion of sampling event # 3- Append. II detected + Appendix I
Day 90	Completion of sampling event # 4- Append. II detected + Appendix I
Day 120	Submittal of Report of Findings

7.0 REFERENCES

Bradley, Michael W., Ground Water in the Dickson Area of the Western Highland Rim of Tennessee, U.S.G.S. Water- Resources Investigations 82-4088 (Nashville, TN, 1984)

ATEC Associates, Inc., Geotechnical and Hydrogeologic Investigation Proposed Landfill Site for Dickson County, Tennessee, (May, 1992)

Gardener Engineering, "Dickson County Landfill/Balefill Groundwater Contamination Problem" (September, 1994)

APPENDIX A

APPENDIX II. - GROUNDWATER MONITORING LIST

Chlorobenzene	Benzene, chloro-
Chlorobenzilate	Benzeneacetic acid, 4-chloro-a-(4-chlorophenyl)-a-hydroxy, ethyl ester
p-Chloro-m-cresol; 4-Chloro-3-methylphenol	Phenol, 4-chloro-3-methyl-
Chloroethane; Ethyl chloride	Ethane, chloro-
Chloroform; Trichloromethane	Methane, trichloro-
2-Chloronaphthalene	Naphthalene, 2-chloro-
2-Chlorophenol	Phenol, 2-chloro-
4-Chlorophenyl phenyl ether	Benzene, 1-chloro-4-phenoxy-
Chloroprene	1,3-Butadiene, 2-chloro-
Chromium	Chromium
Chrysene	Chrysene
Cobalt	Cobalt
Copper	Copper
m-Cresol; 3-methylphenol	Phenol, 3-methyl-
o-Cresol; 2-methylphenol	Phenol, 2-methyl-
p-Cresol; 4-methylphenol	Phenol, 4-methyl-
Cyanide	Cyanide
2,4-D; 2-4-Dichlorophenoxyacetic acid	Acetic acid, (2,4-dichlorophenoxy)-
4,4'-DDD	Benzene, 1,1'-(2,2-dichloroethylidene) bis(4-chloro-
4,4'-DDE	Benzene, 1,1'-(dichloroethyenylidene) bis(4-chloro-
4,4'-DDT	Benzene, 1,1'-(2,2,2-trichloroethylidene)bis(4-chloro-
Diallate	Carbamothioic acid, bis(1-methylethyl)-, S-(2,3-dichloro-2-propenyl) ester

Dibenz[a,h]anthracene	Dibenz[a,h]anthracene
Dibenzofuran	Dibenzofuran
Dibromochloromethane; Chlorodibromomethane	Methane, dibromochloro-
1,2-Dibromo-3-chloropropane; DBCP	Propane, 1,2-dibromo-3-chloro-
1,2-Dibromoethane; Ethylene dibromide; EDB	Ethane, 1,2-dibromo-
Di-n-butyl phthalate	1,2-Benzenedicarboxylic acid, dibutyl ester
o-Dichlorobenzene; 1,2-Dichlorobenzene	Benzene, 1,2-dichloro-
m-Dichlorobenzene; 1,3-Dichlorobenzene	Benzene, 1,3-dichloro-
p-Dichlorobenzene; 1,4-Dichlorobenzene	Benzene, 1,4-dichloro-
3,3'-Dichlorobenzidine	[1,1'-Biphenyl]-4,4'-diamine, 3,3'-dichloro-
trans-1,4-Dichloro-2-butene	2-Butene, 1,4-dichloro-, (E)-
Dichlorodifluoromethane; CFC 12;	Methane, dichlorodifluoro-
1,1-Dichloroethane; Ethyldidene chloride	Ethane, 1,1-dichloro-
1,2-Dichloroethane; Ethylene dichloride	Ethane, 1,1-dichloro-
1,1-Dichloroethylene; Vinylidene chloride; 1,1-Dichloroethene	Ethene, 1,1-dichloro-
cis-1,2-Dichloroethylene; cis-1,2-Dichloroethene	Ethene, 1,2-dichloro-,(Z)-
trans-1,2-Dichloroethylene trans-1,2-Dichloroethene	Ethene, 1,2-dichloro-,(E)-
2,4-Dichlorophenol	Phenol, 2,4-dichloro-
2,6-Dichlorophenol	Phenol, 2,6-dichloro-

1,2-Dichloropropane; Propylene dichloride	Propane, 1,2-dichloro-
1,3-Dichloropropane; Trimethylene dichloride	Propane, 1,3-dichloro-
2,2-Dichloropropane; Isopropylidene chloride	Propane, 2,2-dichloro-
1,1-Dichloropropene	1-Propene, 1,1-dichloro-
cis-1,3-Dichloropropene	1-Propene, 1,3-dichloro-,(Z)-
trans-1,3-Dichloropropene	1-Propene, 1,3-dichloro-,(E)-
Dieldrin	2,7:3,6-Dimethanonaphth[2,3-b]oxirene, 3,4,5,6,9,9-hexachloro-1a,2,2a,3,6,6a, 7,7a-octahydro-, (1aa,2B,2aa,3B,6B, 6aa,7B,7aa)-
Diethyl phthalate	1,2-Benzenedicarboxylic acid, diethyl ester
O,O-Diethyl O-2-pyrazinyl-phosphorothioate; Thionazin	Phosphorothioic acid, O,O-diethyl O-pyrazinyl ester
Dimethoate	Phosphorodithioic acid, O,O-dimethyl S-[2-(methylamino)-2-oxoethyl] ester
p-(Dimethylamino)azobenzene	Benzenamine, N,N-dimethyl-4-(phenylazo)-
7,12-Dimethylbenz[a]anthracene	Benz[a]anthracene, 7,12-dimethyl-
3,3'-Dimethylbenzidine	[1,1'-Biphenyl]-4,4'-diamine, 3,3'-dimethyl-
2,4-Dimethylphenol; m-xylenol	Phenol, 2,4-dimethyl-
Dimethyl phthalate	1,2-Benzenedicarboxylic acid, dimethyl ester
m-Dinitrobenzene	Benzene, 1,3-dinitro-
4,6-Dinitro-o-cresol; 4,6-Dinitro2-methylphenol	Phenol, 2-methyl-4,6-dinitro-
2,4-Dinitrophenol	Phenol, 2,4-dinitro-
2,4-Dinitrotoluene	Benzene, 1-methyl-2,4-dinitro-
2,6-Dinitrotoluene	Benzene, 2-methyl-1,3-dinitro-

Dinoseb; DNBP; 2-sec-Butyl-4,6-dinitrophenol	Phenol, 2-(1-methylpropyl)-4,6-dinitro-
Di-n-octyl phthalate	1,2-Benezenedicarboxylic acid, dioctyl ester
Diphenylamine	Benzenamine, N-phenyl-
Disulfoton	Phosphorodithioic acid, O,O-diethyl S-[2-(ethylthio)ethyl] ester
Endosulfan I	6,9-Methano-2,4,3-benzodioxathiepin, 6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-, 3-oxide,
Endosulfan II	6,9-Methano-2,4,3-benzodioxathiepin, 6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-, 3-oxide, (3a,5aa,6B,9B,9aa)-
Endosulfan sulfate	6,9-Methano-2,4,3-benzodioxathiepin, 6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-,3-3-dioxide
Endrin	2,7:3,6-Dimethanonaphth[2,3-b]oxirene, 3,4,5,6,9,9-hexachloro-1a,2,2a,3,6,6a,7,7a-octahydro-, (1aa,2B,2aB,3a,6a,6aB,7B,7aa)-
Endrin aldehyde	1,2,4-Methenocyclopenta[cd]pentalene-5-carboxaldehyde,2,2a,3,3,4,7-hexachlorodecahydro-, (1a,2B,2aB,4B,4aB,5B,6aB,6bB,7R*)-
Ethylbenzene	Benzene, ethyl-
Ethyl methacrylate	2-Propenoic acid, 2-methyl-, ethyl ester
Ethyl methanesulfonate	Methanesulfonic acid, ethyl ester
Famphur	Phosphorothioic acid, O-[4-[(dimethylamino)sulfonyl]phenyl] O,O-dimethyl ester
Fluoranthene	Fluoranthene
Fluorene	9H-Fluorene
Heptachlor	4,7-Methano-1H-indene, 1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-

Heptachlor epoxide	2,5-Methano-2H-indeno[1,2-b]oxirene, 2,3,4,5,6,7,7-heptachloro-1a,1b, 5,5a,6,6a-hexahydro-, (1aa,1bB, 2a,5a,5aB,6B,6aa)
Hexachlorobenzene	Benzene, hexachloro-
Hexachlorobutadiene	1,3-Butadiene, 1,1,2,3,4,4-hexachloro-
Hexachlorocyclopentadiene	1,3-Cyclopentadiene, 1,2,3,4,5,5-hexachloro-
Hexachloroethane	Ethane, hexachloro-
Hexachloropropene	1-Propene, 1,1,2,3,3,3-hexachloro-
2-Hexanone; Methyl butyl ketone	2-Hexanone
Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene
Isobutyl alcohol	1-Propanol, 2-methyl-
Isodrin	1,4,5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexachloro-,1,4,4a,5,8,8a-hexahydro-(1a,4a,4aB,5B,8B,8aB)-
Isophorone	2-Cyclohexen-1-one, 3,5,5-trimethyl-
Isosafrole	1,3-Benzodioxole, 5-(1-propenyl)-
Kepone	1,3,4-Metheno-2H-cyclobuta[cd]pentalen-2-one,1,1a,3,3a,4,5,5,5a,5b,6-decachlorooctahydro-
Lead	Lead
Mercury	Mercury
Methacrylonitrile	2-Propenenitrile, 2-methyl-
Methapyrilene	1,2-Ethanediamine, N,N-dimethyl-N'-2-pyridinyl-N'-(2-thienylmethyl)-
Methoxychlor	Benzene, 1,1'-(2,2,2,trichloroethylidene)bis(4-methoxy-
Methyl bromide; Bromomethane	Methane, bromo-
Methyl chloride; Chloromethane	Methane, chloro-

3-Methylcholanthrene	Benz[j]aceanthrylene, 1,2-dihydro-3-methyl-
Methyl ethyl ketone; MEK; 2-Butanone	2-Butanone
Methyl iodide; iodomethane	Methane, iodo-
Methyl methacrylate	2-Propenoic acid, 2-methyl-, methyl ester
Methyl methanesulfonate	Methanesulfonic acid, methyl ester
2-Methylnaphthalene	Naphthalene, 2-methyl-
Methyl parathion; Parathion methyl	Phosophorothioic acid, O,O-dimethyl O-(4-nitrophenyl) ester
4-Methyl-2-pentanone; Methyl isobutyl ketone	2-Pentanone, 4-methyl-
Methylene bromide; Dibromomethane	Methane, dibromo-
Methylene chloride; Dichloromethane	Methane, dichloro-
Naphthalene	Naphthalene
1,4-Naphthoquinone	1,4-Naphthalenedione
1-Naphthylamine	1-Naphthalenamine
2-Naphthylamine	2-Naphthalenamine
Nickel	Nickel
o-Nitroaniline; 2-Nitroaniline	Benzenamine, 2-nitro-
m-Nitroaniline; 3-Nitroaniline	Benzanamine, 3-nitro-
p-Nitroaniline; 4-Nitroaniline	Benzenamine, 4-nitro-
Nitrobenzene	Benzene, nitro-
o-Nitrophenol; 2-Nitropherol	Phenol, 2-nitro
p-Nitrophenol; 4-Nitrophenol	Phenol, 4-nitro-
N-Nitrosodi-n-butylamine	1-Butanamine, N-butyl-N-nitroso-

N-Nitrosodiethylamine	Ethanamine, N-ethyl-N-nitroso-
N-Nitrosodimethylamine	Methanamine, N-methyl-N-nitroso-
N-Nitrosodiphenylamine	Benzenamine, N-nitroso-N-phenyl-
N-Nitrosodipropylamine; Di-n-propylnitrosamine; N-Nitroso-N-dipropylamine	1-Propanamine, N-nitroso-N-propyl
N-Nitrosomethylethalamine	Ethanamine, N-methyl-N-nitroso-
N-Nitrosopiperidine	Piperidine, 1-nitroso-
N-Nitrosopyrrolidine	Pyrrolidine, 1-nitroso-
5-Nitro-o-toluidine	Benzenamine, 2-methyl-5-nitro-
Parathion	Phosphorothioic acid, O,O-diethyl-O-(4-nitrophenyl) ester
Pentachlorobenzene	Benzene, pentachloro-
Pentachloronitrobenzene	Benzene, pentachloronitro-
Pentachlorophenol	Phenol, pentachloro-
Phenacetin	Acetamide, N-(4-ethoxyphenyl)
Phenanthrene	Phenanthrene
Phenol	Phenol
p-Phenylenediamine	1,4-Benzenediamine
Phorate	Phosphorodithioic acid, O,O-diethyl S-[(ethylthio)methyl] ester
Polychlorinated biphenyls; PCBs, Aroclors	1,1'-Biphenyl, chloro derivatives
Pronamide	Benzamide, 3,5-dichloro-N-(1,1-dimethyl-2-propynyl)-
Propionitrile; Ethyl cyanide	Propanenitrile
Pyrene	Pyrene
Safrole	1,3-Benzodioxole, 5-(2-propenyl)-

Selenium	Selenium
Silver	Silver
Silvex; 2,4,5-TP	Propanoic acid, 2-(2,4,5-trichlorophenoxy)-
Styrene	Benzene, ethenyl-
Sulfide	Sulfide
2,4,5-T; 2,4,5-Trichlorophenoxyacetic acid	Acetic acid, (2,4,5-trichlorophenoxy)-
1,2,4,5-Tetrachlorobenzene	Benzene, 1,2,4,5-tetrachloro-
1,1,1,2-Tetrachloroethane	Ethane, 1,1,1,2-tetrachloro-
1,1,2,2-Tetrachloroethane	Ethane, 1,1,2,2-tetrachloro-
Tetrachloroethylene; Tetrachloroethene; Perchloroethylene	Ethene, tetrachloro-
2,3,4,6-Tetrachlorophenol	Phenol, 2,3,4,6-tetrachloro-
Thallium	Thallium
Tin	Tin
Toluene	Benzene, methyl-
o-Toluidine	Benzenamine, 2-methyl-
Toxaphene	Toxaphene
1,2,4-Trichlorobenzene	Benzene, 1,2,4-trichloro-
1,1,1-Trichloroethane; Methylchloroform	Ethane, 1,1,1-trichloro-
1,1,2-Trichloroethane	Ethane, 1,1,2-trichloro-
Trichloroethylene; Trichloroethene	Ethene, trichloro
Trichlorofluoromethane; CFC-11	Methane, trichlorofluoro-
2,4,5-Trichlorophenol	Phenol, 2,4,5-trichloro-
2,4,6-Trichlorophenol	Phenol, 2,4,6-trichloro-

1,2,3-Trichloropropane	Propane, 1,2,3-trichloro-
O,O,O-Triethyl phosphorothioate	Phosphorothioic acid, O,O,O-triethylester
sym-Trinitrobenzene	Benzene, 1,3,5-trinitro-
Vanadium	Vanadium
Vinyl acetate	Acetic acid, ethenyl ester
Vinyl chloride; Chloroethene	Ethene, chloro-
Xylene (total)	Benzene, dimethyl-
Zinc	Zinc

APPENDIX B

SAMPLING AND ANALYSIS
QUALITY ASSURANCE/QUALITY CONTROL PLAN

QUALITY ASSURANCE / QUALITY CONTROL PLAN

SAMPLING AND ANALYSIS
OF
GROUNDWATER MONITORING WELLS

PREPARED FOR

DICKSON COUNTY

JUNE, 1994

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LIST OF APPENDICES

QUALITY ASSURANCE / QUALITY CONTROL PLAN
SAMPLING AND ANALYSIS
OF
GROUNDWATER MONITORING WELLS

1. INTRODUCTION

This document is prepared for the State of Tennessee Department of Environment and Conservation, Division of Solid/Hazardous Waste Management to establish Quality Control and Quality Assurance guidelines. These guidelines are to be followed throughout the groundwater assessment monitoring period at the Dickson County Class I Landfill.

This plan covers the complete process utilized for the collection of quality groundwater monitoring samples including the:

- measurement of groundwater levels
- detection / measurement of immiscible layers
- purging of wells
- sample collection, handling, and analysis
- quality control and quality assurance

2. GROUNDWATER LEVEL AND WELL DEPTH MEASUREMENT

2.1. STATIC WATER LEVEL

The depth to water level in the wells must be measured to calculate the casing water volume for purging and also for the purpose of determining the hydrological groundwater characteristics.

The static water level in the well is measured prior to the well evacuation. Initial static water levels are measured typically seven to ten days after installation and development of a new well and additional measurements are performed prior to each purging and sampling event. All water level measurements utilized to construct a piezometric surface map must be obtained within a consecutive twenty-four (24) hour period.

2.1. STATIC WATER LEVEL, Cont'd

The water level elevation will be determined to the nearest 0.01 feet as measured with a water level meter. The meter consist of a reel containing a length of weighted, marked fiberglass tape, which has a conducting probe attached to detect the air/water interface, and an alarm.

The water level measurement is performed three (3) times to insure accuracy and water level stability. Always measure the upgradient or background wells first to reduce the potential for cross contamination.

The following procedure will be followed for water level measurement in groundwater monitoring wells.

A) Prepare a "Monitoring Well Purging and Sampling" (MWP&S) form (Appendix A) for each well to be measured, and enter all reference information for each well.

B) Locate the well identification on the casing and the well elevation reference mark and check against the site map for verification. If identification or elevation markings are not found on the well, verify the well identification and mark the well with the identification number and an elevation mark. Note the changes on the MWP&S form and inform the project manager. If a new elevation mark is placed on the well, a survey must be performed.

C) Place a plastic sheet on the ground surrounding the well by cutting a slit in a piece of plastic and inserting over the well. The plastic sheet should be of sufficient size to prevent contamination of equipment and supplies during the water level measurement process.

D) Unlock and open the protective well cover and the well cap. Note the well condition and any odors observed on the MWP&S form.

E) Sample the well headspace for volatile organics with an HNU-101 photoionization detector (previously calibrated) and record the HNU reading on the MWP&S form.

F) Put on a clean pair of unpowdered, disposable gloves. (When gloves become soiled or damaged replace with a clean pair). Dispose of used gloves as per instructions in Section 11.0.

G) Determine if the water level tape and probe has been decontaminated. If not, wash with soap and water, and rinse with DI water. Dispose of wash and rinse water as per instructions in Section 11.0.

2.1. STATIC WATER LEVEL, Cont'd

H) Check the probe sensor and battery by immersing the probe in water. Note the level of the water on the electrode sensor when the alarm just begins to sound. If the probe operation is normal, proceed with item I. If the alarm does not sound when the electrode tip contacts the water's surface, determine what is causing the malfunction before proceeding or obtain another water level meter.

I) Lower the probe and tape into the well carefully and slowly. Do not allow the tape to contact the well casing to prevent damage to the tapes surface. Surface abrasions will cause difficulty with later cleaning and decontamination.

J) When the probe contacts the water surface and the alarm sounds, retrieve the probe until the alarm just ceases. Continue lowering and raising the probe until the point where the alarm just begins to sound is determined.

K) Hold the tape against the well elevation mark on the casing.

L) Note and record on the MWP&S form the distance from the well elevation mark to the groundwater's surface to the nearest 0.01 feet.

M) Repeat parts I-L two more times to verify the measurements. If the measurements are not constant, continue to measure at greater time intervals until the levels stabilize. The elevation of the well minus the distance to the water surface is equal to the elevation of the water.

N) To measure the total well depth, lower the weighted tape slowly to the bottom of the well.

O) Mark the tape and read at the well elevation reference mark to the nearest 0.01 feet.

P) Record the distance from the well elevation reference mark to the well bottom on the MWP&S log sheet.

Q) Remove the tape and probe from the well being careful not to allow the tape to rub on the well pipe or casing.

R) Replace the well cap and lock the well or continue with purging and sampling.

S) If free product or gross contamination are not encountered or suspected, wash the tape with soap and water and DI water rinse after each use. If free product or gross contamination are encountered or suspected, rinse the tape and probe with alcohol, rinse with water, wash with soap and water and DI water rinse and finally rinse with alcohol and then DI water. The tape and probe must be washed with soap and water and rinsed with alcohol and DI water prior to use in another well.

2.1. STATIC WATER LEVEL, Cont'd

S) All wash and rinse water and alcohol rinse must be collected and held for proper disposal according to the guidelines set forth in Section 11.0.

3. DETECTION AND SAMPLING OF IMMISCIBLE LAYERS

3.1. DETECTION OF IMMISCIBLE LAYERS

After opening the well, sample the well vapor space with an HNU-101 Photoionization Detector. If, after opening the well, the HNU indicates detectable levels of organics, a floating layer is indicated, and must be measured and sampled as set forth in the following section. If the HNU does not indicate detectable levels of volatile organics it will be assumed that no floating immiscible organic layer is present, and work will continue to purge and sample the wells.

3.2. SAMPLING OF IMMISCIBLE LAYERS

If immiscible layering is detected in any of the wells, samples of the immiscible layer must be collected prior to purging. For floating layers, samples will be collected with a disposable bailer, or a peristaltic pump if the layer is located within 25 feet of the surface. For bottom layers a double valve bailer will be utilized.

3.3. SAMPLING PROCEDURES FOR IMMISCIBLE LAYERS

The following procedure will be followed for sampling of immiscible layers in groundwater monitoring wells.

A) Prepare a "Monitoring Well Purging and Sampling" (MWP&S) form (Appendix A) for each well to be measured, and enter all reference information for each well.

B) Locate the well identification on the casing and the well elevation reference mark and check against the site map for verification. If identification or elevation markings are not found on the well, verify the well identification and mark the well with the identification number and an elevation mark. Note the changes on the MWP&S form and inform the project manager. If a new elevation mark is placed on the well, a survey must be performed.

3.3. SAMPLING PROCEDURES FOR IMMISCIBLE LAYERS, Cont'd

C) Place a plastic sheet on the ground surrounding the well by cutting a slit in a piece of plastic and inserting over the well. The plastic sheet should be of sufficient size to prevent contamination of equipment and supplies during the water level measurement process.

D) Unlock and open the protective well cover and the well cap. Note the well condition and any odors observed on the MWP&S form.

E) Sample the well headspace for volatile organics with an HNU-101 photoionization detector (previously calibrated) and record the HNU reading on the MWP&S form.

F) Put on a clean pair of unpowdered, disposable gloves. (When gloves become soiled or damaged replace with a clean pair). Dispose of used gloves as per instructions in Section 11.0.

G) Determine the static water level following procedures in Section 1.1.

H) Lower a previously cleaned bailer slowly into the well to the interval being sampled. If the layer is only a few inches thick, use an open top bailer and lower the bailer an

I) Raise the bailer to the surface carefully. Do not allow the bailer or bailer cord to contact the ground.

J) Remove the cap from the VOA vial, and tilt slightly.

K) Pour the sample slowly into the vial to avoid spillage and air entrainment, making sure to quantitatively transfer any sediment in the sample. Fill the vial to overflowing to provide for a zero airspace sample, and cap. Invert, tap the vial with a finger and check for air bubbles. If bubbles appear repeat the filling process.

L) Label, package, and store the sample according to instructions in Sections 8.0 and 9.0 for sample handling and documentation.

M) Replace the well cap and lock the well.

N) Rinse the water level tape and probe with alcohol, rinse with water, wash with soap and water and DI water rinse and finally rinse with alcohol and then DI water. The tape and probe must be washed with soap and water and rinsed with alcohol and DI water prior to use in another well.

O) Wash and rinse all equipment prior to leaving the site.

3.3. SAMPLING PROCEDURES FOR IMMISCIBLE LAYERS, CONT'D

P) All wash and rinse water and alcohol rinse must be collected and held for proper disposal according to the guidelines set forth in Section 11.0.

Q) Dispose of all contaminated materials, gloves, etc. according to the guidelines set forth in Section 11.0.

4. WELL PURGING

4.1. GROUNDWATER MONITORING WELLS PURGING

The water standing in the well prior to sampling may not be representative of the in-situ ground water quality. Therefore the standing water in the well and filter pack will be removed so that fresh water from the aquifer can replace the stagnant water.

If the well is in a high yield formation the well will be evacuated from above the sand pack to draw fresh water up through the well. The most efficient exchange of water in the well is effected by pumping from near the top of the water column. This causes the stagnant water in the casing above the filter screen to be evacuated first.

A minimum of three (3) well volumes of water will be evacuated from the well. The capacity for the well to recharge and the draw down of the water column should be noted for future reference.

Low yield wells will be evacuated to dryness and allowed to recharge slowly. Whenever full recovery of the water in the well exceeds two hours, samples will be collected as sufficient water becomes available. When the recharge rate is less than two (2) hours, monitor the water quality (pH, Conductivity, and Temperature) until the readings become stable, indicating the well has been sufficiently purged.

Peristaltic, submersible purge, and/or positive gas displacement Teflon bladder pumps, and/or disposable bailers will be utilized to evacuate the wells prior to sampling. Disposable polyethylene bailers may be used if free product will not be encountered in the well.

Peristaltic pumps may be utilized when the water lift is less than twenty-five (25) feet. At depths exceeding twenty-five (25) feet, submersible purge or positive displacement pumps or bailers will be used. Bailers may be utilized in all wells, although the limited capacity of the bailer makes their use laborious. When using bailers lower and raise slowly to prevent agitation of the water in the well.

4.1. GROUNDWATER MONITORING WELLS PURGING, Cont'd

Care will be taken to protect the bailer, pumps, suspension cords, tubing and cables from contacting the areas surrounding the well. A plastic sheet will be utilized to cover the ground and well opening area to protect the equipment.

When lowering the pumping equipment into the well, the pump and tubing will be supported to prevent it from dragging on the top of the well casing or binding when being lowered or raised.

The well may be considered to be evacuated when the water becomes clear and sufficient quantity has been evacuated (3x volume of water in the well). Purged water will be collected and screened to determine if it may be hazardous. If the possibility the purged water contains hazardous contaminant levels which exceed those levels which may endanger the health of personnel or the environment, the water will be drummed and held for proper disposal by post treatment on site or disposal by certified waste disposal handlers.

4.2. PURGING PROCEDURES FOR GROUNDWATER MONITORING WELLS

The following procedure will be followed for purging of groundwater from the monitoring wells:

A) Prepare a "Monitoring Well Purging and Sampling" (MWP&S) form (Appendix A) for each well to be measured, and enter all reference information for each well.

B) Locate the well identification on the casing and the well elevation reference mark and check against the site map for verification. If identification or elevation markings are not found on the well, verify the well identification and mark the well with the identification number and an elevation mark. Note the changes on the MWP&S form and inform the project manager. If a new elevation mark is placed on the well, a survey must be performed.

C) Place a plastic sheet on the ground surrounding the well by cutting a slit in a piece of plastic and inserting over the well. The plastic sheet should be of sufficient size to prevent contamination of equipment and supplies during the water level measurement process.

D) Unlock and open the protective well cover and the well cap. Note the well condition and any odors observed on the MWP&S form.

E) Sample the well headspace for volatile organics with an HNU-101 photoionization detector (previously calibrated) and record the HNU reading on the MWP&S form.

4.2. PURGING PROCEDURES FOR GROUNDWATER MONITORING WELLS, Cont'd

F) Put on a clean pair of unpowdered, disposable gloves. (When gloves become soiled or damaged, replace with a clean pair). Dispose of used gloves as per instructions in Section 11.0.

G) Determine the static water level following procedures in Section 1.1.

H) Determine the purging method to be followed.

I) Calculate the volume of water in the well from information gathered when measuring the well depth and static water level by one of the following methods:

Depth of well – Depth to water = Height of water column

1) BY FORMULA:

$r^2 \times h \times 7.481$ = gallons of water

where: r = radius of the well pipe in feet

h = height of water column in the well

7.481 = gallons/cubic foot of water

2) BY WELL PIPE SIZE:

a) For 2" diameter wells:

Gallons = 0.1632 (gal/ft) X h (ft)

when h = height of water column in the well

b) For 4" diameter wells:

Gallons = 0.6528 (gal/ft) X h (ft)

when h = height of water column in the well

c) For 6" diameter wells:

Gallons = 1.4688 (gal/ft) X h (ft)

when h = height of water column in the well

Record the purge volume on the MWP&S form.

J) Sample the water in the well and test for pH, specific conductance, and temperature. Record results on the MWP&S form.

4.2. Purging Procedures For Groundwater Monitoring Wells, Cont'd

K) Purge the calculated volume of water from the well.

L) All purged water from the wells will be collected in tanks or drums for later analysis, treatment and disposal.

M) Repeat items J and K two additional times to purge a minimum of three (3) well volumes from the well when the recharge rate is sufficient.

N) Record all purge times, volumes, and water quality test results on the MWP&S form.

O) Rinse the purge pump or bailer (if not dedicated) with DI water and combine the rinse water with the purge water for disposal.

P) Wash and rinse all equipment prior to leaving the site.

Q) Wash the pumps and bailers with soap and water, rinse with DI water, rinse with alcohol, and finally with DI water prior to use in other wells. Combine the washings and rinse water with the purge water for disposal per the instructions in Section 11.0.

R) Samples will be collected as soon as possible after purging, allowing sufficient time for the well to recharge.

S) Replace the well cap and lock the well.

T) Dispose of all contaminated materials, gloves, etc. according to the guidelines set forth in Section 11.0.

5. SAMPLE COLLECTION

5.1. Sample Integrity

To ensure the sample collected is representative of the formation, it is important to minimize physically altering or chemically contaminating the sample during the collection process.

Care will be taken to protect the sampling equipment, tubing and cables from contacting the areas surrounding the well. A plastic sheet will be utilized to cover the ground and well opening area to protect the equipment.

5.2. SAMPLE COLLECTION - BAILER

A bailer is a long cylindrical tube constructed of materials which will not alter the quality of the sample being collected. Bailers used will not have glued joints. Bailers used at the site will be of the disposable, bottom-fill type, constructed of polyethylene.

The bailer will be lowered into the well by a line into the groundwater where it fills from the bottom. The bailer has a ball, which seals the bottom of the bailer to prevent the water from emptying when the bailer is lifted from the well.

5.3. SAMPLING PROCEDURES FOR BAILERS

The following procedure will be followed for sampling of groundwater in monitoring wells when using bailers.

A) Prepare a "Monitoring Well Purging and Sampling" (MWP&S) form (Appendix A) for each well to be measured, and enter all reference information for each well.

B) Locate the well identification on the casing and the well elevation reference mark and check against the site map for verification. If identification or elevation markings are not found on the well, verify the well identification and mark the well with the identification number and an elevation mark. Note the changes on the MWP&S form and inform the project manager. If a new elevation mark is placed on the well, a survey must be performed.

C) Place a plastic sheet on the ground surrounding the well by cutting a slit in a piece of plastic and inserting over the well. The plastic sheet should be of sufficient size to prevent contamination of equipment and supplies during the water level measurement process.

D) Unlock and open the protective well cover and the well cap. Note the well condition and any odors observed on the MWP&S form.

E) Sample the well headspace for volatile organics with an HNU-101 photoionization detector (previously calibrated) and record the HNU reading on the MWP&S form. Determine if immiscible layers are present (Section 2.0).

F) Put on a clean pair of unpowdered, disposable gloves. (When gloves become soiled or damaged replace with a clean pair). Dispose of used gloves as per instructions in Section 11.0.

G) Determine the static water level following procedures in Section 1.1.

5.3. Sampling Procedures For Bailers, Cont'd

H) Purge the well of the required three (3) well volumes of groundwater or to dryness.

I) Attach new line to a new disposable bailer or use a dedicated bailer for each well to be sampled.

J) Carefully and slowly lower the bailer to the groundwater surface.

K) Allow the bailer to fill slowly with a minimum of water surface agitation to prevent aeration.

L) Raise the filled bailer to the surface while protecting the line from becoming contaminated.

M) Remove the cap from the VOA vial, and tilt slightly.

N) Pour the sample slowly into the vial to avoid spillage and air entrainment, making sure to quantitatively transfer any sediment in the sample. Fill the vial to overflowing to provide for a zero airspace sample, and cap. Invert, tap the vial with a finger and check for air bubbles. If bubbles appear repeat the filling process.

O) Properly dispose of excess sample collected from the well by combining with the purge water or wash water.

P) Label, package, and store the sample according to instructions in Sections 8.0 and 9.0 for sample handling and documentation.

Q) Replace the well cap and lock the well.

R) Wash and rinse all equipment prior to leaving the site and rinse the exterior of all samples.

S) All wash and rinse water, alcohol rinse water, and excess sample must be collected and held for proper disposal according to the guidelines set forth in Section 11.0.

T) Dispose of all contaminated materials (bailers, line, plastic sheeting, gloves, etc.) according to the guidelines set forth in Section 11.0.

U) Samples will be labeled, packaged, stored, and shipped according to the guidelines set forth in Sections 8.0 and 9.0 of this plan.

V) Complete the required chain-of-custody and documentation for the sampling.

5.4. Sample Collection - Bladder Pump

A bladder pump is a long cylindrical tube with a flexible air operated bladder, constructed of materials which will not alter the quality of the sample being collected. Bladder pumps operate by alternately inflating and deflating the flexible bladder to alternately withdraw water from the well and pump the water to the surface.

5.5. Sampling Procedures For Bladder Pumps

The following procedure will be followed for sampling of groundwater in monitoring wells when using bladder pumps.

A) Prepare a "Monitoring Well Purging and Sampling" (MWP&S) form (Appendix A) for each well to be measured, and enter all reference information for each well.

B) Locate the well identification on the casing and the well elevation reference mark and check against the site map for verification. If identification or elevation markings are not found on the well, verify the well identification and mark the well with the identification number and an elevation mark. Note the changes on the MWP&S form and inform the project manager. If a new elevation mark is placed on the well, a survey must be performed.

C) Place a plastic sheet on the ground surrounding the well by cutting a slit in a piece of plastic and inserting over the well. The plastic sheet should be of sufficient size to prevent contamination of equipment and supplies during the water level measurement process.

D) Unlock and open the protective well cover and the well cap. Note the well condition and any odors observed on the MWP&S form.

E) Sample the well headspace for volatile organics with an HNU-101 photoionization detector (previously calibrated) and record the HNU reading on the MWP&S form. Determine if immiscible layers are present (Section 2.0).

F) Put on a clean pair of unpowdered, disposable gloves. (When gloves become soiled or damaged, replace with a clean pair). Dispose of used gloves as per instructions in Section 11.0.

G) Determine the static water level following procedures in Section 1.1.

H) Purge the well of the required three (3) well volumes of groundwater or to dryness.

I) Attach the compressor lines to the gas control box.

5.5. SAMPLING PROCEDURES FOR BLADDER PUMPS, Cont'd

J) Connect the battery to the gas control box.

K) Attach the support line and compressed gas lines from the gas control box, to the previously decontaminated bladder pump.

L) Lower the pump and tubing into the well carefully to prevent the tubing from and support cable from becoming contaminated or rubbing on the well casing or protective cover which may damage or contaminate the pump or tubing.

M) When the pump has been lowered to the prescribed depth, secure the support line and turn on the power and compressed air.

N) Adjust the gas control box to the desired pump and fill cycle time to optimize the pumping rate.

O) Remove the cap from the VOA vial, and tilt slightly.

P) Allow the water being discharged from the pump to be slowly discharged into a precleaned 40-ml VOA vial. Fill the vial slowly to avoid entrainment of air, making sure to quantitatively transfer any sediment in the sample. Fill the vial to overflowing to provide for a zero airspace sample, and cap. Invert, tap the vial with a finger and check for air bubbles. If bubbles appear repeat the filling process.

Q) Properly dispose of excess sample collected from the well by combining with the purge water or wash water.

R) Label, package, and store the sample according to instructions in Sections 8.0 and 9.0 for sample handling and documentation.

S) Remove the pump and tubing from the well, being careful not to damage the well casing, pump, or tubing.

T) Collect all water from the pump and tubing, flush with potable water (inside and outside), collecting all water drained from the pump and tubing and rinse waters for proper disposal.

U) Replace the well cap and lock the well.

V) Wash and rinse all equipment prior to leaving the site and rinse the exterior of the sample container.

W) All wash and rinse water, alcohol rinse water, and excess sample must be collected and held for proper disposal according to the guidelines set forth in Section 11.0.

5.5. Sampling Procedures For Bladder Pumps, Cont'd

J) Dispose of all contaminated materials (plastic sheeting, gloves, etc.) according to the guidelines set forth in Section 11.0.

K) Samples will be labeled, packaged, stored, and shipped according to the guidelines set forth in other sections of this plan.

L) Complete the required chain-of-custody and documentation for the sampling.

6. FIELD MEASUREMENT PROCEDURES

6.1. Field Measurement Procedure - Temperature

The measurement of temperature during the purging and sampling of monitoring wells is required to monitor the purging process. Temperature will be measured by use of a glass thermometer which is stored in a plastic case.

Samples of water from the well are taken and prior to purging and at intervals during the purging process. The thermometer is inserted in the sample as soon as possible after withdrawing the water from the well, swirled to mix, and read when the thermometer fluid column has stabilized.

The temperature is recorded and the sample utilized for the measurement of pH and specific conductance. The thermometer is dried by wiping gently, and stored in its protective case.

6.2. Field Measurement Procedure - pH

The pH of the groundwater sample is determined electrometrically with a combination glass pH electrode. The following procedure will be utilized for pH measurements:

A) Collect a fresh sample of the groundwater to be tested or use the sample used for the measurement of temperature.

B) Measure and note the temperature of a sample of pH=7 buffer solution.

C) Measure and note the temperature of a sample of either pH=4 or pH=10 buffer solutions (to bracket the pH of the groundwater). The temperature of the pH=7 and the other buffer used should be the same.

D) Turn on instrument power, select pH mode, remove the electrode protective cover and rinse with DI water.

6.2. FIELD MEASUREMENT PROCEDURE - PH, Cont'd

E) Check the calibration of the pH meter by immersing the electrode in a fresh sample of standard pH 7 buffer solution.

F) Slide back the battery compartment cover exposing the adjustment pots.

G) Adjust the CAL (calibrate) pot until the display reads 7.00.

H) Remove the electrode from the pH=7 buffer solution and rinse the electrode with DI water.

I) Check the slope of the pH meter by immersing the electrode in a fresh sample of standard pH=4 or pH=10 buffer solution.

J) Adjust the SLOPE pot until the display reads the value of the buffer being used.

K) Remove the electrode from the buffer solution and rinse the electrode with DI water.

L) Immerse the electrode into a sample of the groundwater which is at the same temperature as the buffering standard solutions.

M) Swirl or mix slowly until the reading stabilizes.

N) Read and record the value of the pH.

O) Dispose of the sample and wash water properly.

P) Turn off the power switch.

Q) Rinse the electrode thoroughly with DI water and replace the protective electrode cap.

R) The electrode should be rinsed with DI water after each test. Contain all rinse waters for proper disposal.

S) Calibrate the meter with buffers within 3.0 pH units of the test sample.

T) Place pH=7 buffer solution in the protective electrode cap.

U) Remove the battery when the meter will not be used for long periods of time to prevent the battery from leaking or corroding the meter.

6.3. Field Measurement Procedure - Specific Conductivity

The specific conductance of the groundwater sample is determined with a digital conductivity probe. The following procedure will be utilized for conductivity measurements:

A) Collect a fresh sample of the groundwater to be tested or use the sample used for the measurement of temperature.

B) Measure and note the temperature of a sample of conductivity standard which is near the conductance of the samples to be tested.

C) Check the conductivity probe tip for dried solids. If present rinse with DI water and allow the probe tip to air dry. Turn on instrument power and select the conductivity mode.

D) Slide back the battery compartment cover exposing the adjustment pots.

E) Check the zero of the meter by measuring the conductivity in air. Adjust the meter to zero by adjusting the zero pot. Note: the conductivity probe sensor must be thoroughly air dried prior to the zeroing.

F) Immerse the electrode in the conductivity standard and adjust the SPAN pot until the display reads the correct value for the standard.

G) Remove the electrode from the conductivity standard solution and rinse the electrode with DI water. Contain the rinse water for disposal.

H) Immerse the electrode into a sample of the groundwater which is at the same temperature as the conductivity standard solution.

I) Swirl or mix slowly until the reading stabilizes.

J) Read and record the value of the specific conductance of the sample.

K) Dispose of the sample and wash water properly.

L) Turn off the power switch.

M) Rinse the electrode thoroughly with DI water. Contain all rinse waters for proper disposal.

N) The electrode should be rinsed with DI water after each test.

O) Remove the battery when the meter will not be used for long periods of time to prevent the battery from leaking or corroding the meter.

6.4. Sampling Quality Assurance / Quality Control

Trip blanks, equipment blanks, field blanks, split samples, and duplicate samples are examples of Quality Assurance/ Quality Control (QA/QC) sampling requirements. QA/QC samples are handled, packaged, shipped, and analyzed in the same manner as the regular soil samples. QA/QC samples are introduced into the total measurement system as a means of control and evaluation of the level of contamination and variability of results as contributed by potential artifacts and interferences arising at any point in the measurement process.

QA/QC samples are designed to measure:

1) the integrity of the sample container and sample equipment cleaning process;

2) the actual process of sample collection;

3) the purity of the sample preservation and additive reagents and chemicals;

4) the influence of the site's environmental conditions on the samples (contamination);

5) cross contamination of samples due to improperly cleaned sampling equipment; and

6) indeterminant artifacts introduced during sample transport, from containers, preservatives, cleaning agents, and sampling equipment.

Table 1 summarizes the number and frequency of the QA/QC sample collection.

TABLE 1. QA/QC Sample Requirements Dickson County Landfill

QA/QC SAMPLE TYPE	SAMPLE GROUP	FREQUENCY
TRIP BLANKS	METALS/VOC	1 PER TRIP
EQUIPMENT BLANKS	"	1 PER 20
DUPLICATES	"	1 PER 10
FIELD BLANKS	"	1 PER 20
SPLIT SAMPLES	"	AS REQUESTED

6.4.1. FIELD BLANKS

Field blanks are utilized to evaluate the sample container filling procedure, the effects of environmental contaminants at the site, purity of preservatives or additives.

Field blanks are prepared in the field, on-site, by filling appropriate sample containers with DI water and adding appropriate preservatives and additives as required. The field blank sample is then grouped, handled, stored, and transported with the true samples collected at the site.

Field blanks will be collected at the rate of one (1) sample for each twenty (20) samples collected.

6.4.2. TRIP BLANKS

Trip Blanks are prepared in the laboratory with laboratory grade (distilled or deionized) water. The water is placed into the sample containers to verify their cleanliness before and during the sampling project and, in the case of volatile organics, will monitor the contamination of outside contamination on sample containers and collected samples during transportation and storage.

One trip blank per sample set is to be prepared for each parameter group sampled.

6.4.3. EQUIPMENT BLANKS

Equipment blanks, also known as rinseate blanks, are utilized to monitor the contamination or cross contamination of sampling equipment in the field from deficient field cleaning procedures. The equipment blank also addresses the field preservation procedures, environmental site interference, integrity of the source blank for field cleaning operations, and those concerns singularly addressed by the travel blank.

Samples of distilled or deionized water are taken using a blank water rinse of the particular item of sample equipment. The equipment blank is used for sampling equipment like bailers, pumps, pump tubing, spoons, trowels, hand augers, or corers. The equipment blank is prepared by collection of DI water which is being poured over the sampling equipment during the final rinse. Appropriate preservatives and additives which are required to be added to regular samples, will be added to the equipment blank in like manner.

One equipment blank sample per twenty (20) samples collected will be prepared.

6.4.4. DUPLICATE SAMPLES

Duplicate samples are utilized to monitor the reproducability of the sampling procedures and to provide the laboratory with sufficient sample to perform laboratory matrix spike and duplicate sample analysis. Duplicate samples are essentially identical samples. They are collected, preserved, handled, shipped, stored, and analyzed in the same manner as the regular samples.

One duplicate sample will be collected for each sample set of ten (10) samples collected for submittal to the laboratory.

Split samples are duplicate samples split between two or more parties for separate analysis by unrelated laboratories.

7. CLEANING AND DECONTAMINATION OF SAMPLING EQUIPMENT

7.1. SAMPLE CONTAINERS

Sample containers may be either purchased precleaned or may be cleaned by the laboratory or field team. The 40 ml VOA vials and containers to be used for samples for the pH, temperature, and specific conductivity measurements will precleaned or will be cleaned by the following procedure prior to use.

A. Vials, jars, caps, and lids will be washed with phosphate free detergent and hot water.

B. Rinse thoroughly with hot tap water.

C. Rinse with a solution of 10% nitric acid (CAUTION !!).

D. Rinse with tap water followed with DI water.

E. Rinse twice with isopropyl (or methyl) alcohol and allow to air dry for 24 hours.

F. Wrap with aluminum foil to prevent contamination during storage and transport to the site.

G. All alcohol and acid used for the decontamination process will be collected and disposed of properly whether generated in the laboratory or in the field.

7.2. SAMPLING EQUIPMENT

All sampling equipment used at the site will be disposable polyethylene bailers and will not require additional cleaning.

4) Dibenzofurans/ dibenzo-p-dioxins

5) Mercury

6) Total Metals

7) Cyanide

8) Sulfide

9) pH and Conductivity

11. DISPOSAL OF CONTAMINATED MATERIALS

All equipment, supplies, and waste which may contain or be contaminated with hazardous materials must be contained and handled for proper disposal. The following are examples of possible contaminated materials:

A) Water used for washing, rinsing, or decontaminating of sampling equipment or supplies.

B) Water purged from wells or excess samples.

C) Alcohols and acids from sample container decontamination.

D) Disposable and heavy work gloves.

E) Disposable bailers and bailer support lines.

F) Pump and suction tubing.

G) Plastic sheeting used for ground cover or work surfaces.

11.1. Disposal Of Contaminated Waters

Water from the decontamination, purging and sampling activities must be collected in pails, drums or tanks for proper disposal. After completion of the sample analysis, if the samples contain contaminates at levels which may cause the wash waters to be deemed hazardous, the collected waters will be sampled and analyzed to determine the level of contamination and the proper disposal methodology following rules and regulations in force at the time of disposal.

11.2. Disposal Of Solvents And Acids

Solvents used in the lab and the field for decontamination of sample equipment, supplies, and containers will be disposed of by:

Small quantities of solvents used to rinse cleaned containers and equipment and not believed to have significant levels of contamination will be disposed of by placing in a vented area and allowed to evaporate. Large quantities (> 1 liter) of waste solvents will be collected for disposal following rules and regulations in force at the time of disposal.

Solvents used to rinse contaminated equipment which are believed to have significant levels of contamination will be disposed of by placing in an approved shipping container; sampled and analyzed to determine if it is a hazardous waste; and if determined to be hazardous, disposed of by proper disposal methods following rules and regulations in force at the time of disposal.

Nitric acid utilized for rinsing sampling equipment, containers, and supplies in the laboratory will be collected and disposed of by neutralizing with sodium hydroxide and discharging into the publicly owned treatment works serving the laboratory. Nitric acid utilized in the field will be collected and returned to the laboratory for proper disposal.

11.3. DISPOSAL OF SOLID WASTE

All solid waste including plastic sheeting, bailers, bailer support line, pump and suction tubing, gloves, and trash will be collected and screened with the HNU PID for indications of volatile organics. If the HNU does not indicate volatile organics above the detectable level the waste will be dumped into the site's solid waste containers. If volatile organics are detected the waste will be sampled and analyzed to determine if it is a hazardous waste, and if determined to be hazardous, disposed of by proper disposal methods following rules and regulations in force at the time of disposal.

APPENDIX B

EXAMPLE - SAMPLE LABEL and SEAL

APPENDIX C

CHAIN - OF - CUSTODY

GRIGGS & MALONEY
INCORPORATED
Engineering & Environmental Consulting
745 South Church St., Suite 205
PO Box 2968 (37133-2968)
Murfreesboro, Tennessee 37130
(615) 895-8221 • (615) 895-0632 FAX

CHAIN OF CUSTODY / FIELD DATA SHEET

CLIENT: ______ PROJECT NO.: ______

STREET: ______ CITY ______ STATE/ ZIP: ______

CONTACT: ______ SITE: ______

FACILITY ID NO.: ______ PAGE: ______ OF ______

Sample Description	Type G/C	Matrix/ Source	Collected			Preserved	Qty/ Size	Analysis Requested			
			Date	Time	By						

Remarks / Instructions: ______

Shipped by:
Lab Vehicle ______
Client ______

Relinquished by:	Date	Time	Received by:	Date	Time	Relinquished to Lab:		
						By:	Date:	Time:
Relinquished by:	Date	Time	Received by:	Date	Time	Accepted by Lab:		
						By:	Date:	Time: